OBSERVATIONS

AND

ESSAYS.

BY

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AT THE NEW COLLEGE, MANCHESTER.

———

ST QUODDAM PROBIRE TENUS, SI NON DATUR ULTRA.

HORACE.

———

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PRICE FIVE SHILLINGS.

PREFACE.

WHEN I firſt adopted the reſolution to offer the public, in this manner, the reſult of my meteorological obſervations, which was about twelve months ago, my principal deſign was, to explain the nature of the different inſtruments uſed in meteorology, particularly the barometer and thermometer. As the number of theſe is increaſing daily, many of them muſt fall into hands that are much unacquainted with their principles, and may therefore not profit by them in ſo great a degree as otherwiſe, for which reaſon, a ſhort and clear explanation, with a ſeries of obſervations ſerving further to illuſtrate and exemplify the principles, and a few practical rules for judging of the weather, deduced from experience, ſeemed to me to promiſe utility; whilſt the obſervations themſelves would be an addition to the ſtock already before the public, and might perhaps be found ſubſervient to the improvement of the ſcience.

Soon after this, having diſcovered the relation of the *aurora borealis* to magnetiſm, in the manner deſcribed in the introduction to that eſſay, I found,

I found, that in order to eſtabliſh the diſcovery, a pretty large diſſertation would be required, which muſt, of courſe, be addreſſed more peculiarly to philoſophers; this neceſſarily enlarged the work, and became a primary conſideration, though the original deſign was ſtill kept in view; I concluded afterwards, that the work ſhould conſiſt of two parts, the firſt of which was to contain the ſubſtance of the original deſign, namely, a brief explanation of the nature of the inſtruments, and a digeſt of all the obſervations I had made, as matters of faƈt; the ſecond was to contain the eſſay or diſſertation on the *aurora borealis*, together with ſhort theoretic remarks on the different phenomena of meteorology, which I intended to ſeleƈt chiefly from the beſt accounts I could procure; however, not having by me all the books I could have deſired, I was neceſſarily, and perhaps luckily, forced to contemplate a good deal on the different ſubjeƈts, and to try ſuch experiments as were within my reach. The reſult was, that ſeveral things occurred to me which were new, at leaſt to myſelf, and which throw light on the different branches of natural philoſophy, and of meteorology in particular. Theſe I have thrown into the form of Eſſays, in which are alſo given, ſuch uſeful diſcoveries and obſervations of others as ſeemed neceſſary to be known, in order to form a proper idea of the preſent ſtate of the ſcience, and of the improvements that are yet to be made in it.

In

In the firft part I have given not only the obfervations made at *Kendal* by myfelf, but alfo, with his leave, thofe made at *Kefwick* by Mr. *Crofthwaite*, keeper of the mufeum at that place, together with obfervations on the barometer and rain, made at *London*, for three years, taken from the Philofophical Tranfactions. The refults of the feveral obfervations I have arranged and digefted to the beft of my judgment. The obfervations on the height of the clouds, and on the *aurora borealis*, particularly the fupplemental ones, are new, and, I fuppofe, in fome refpects, original, having never feen any other of a fimilar nature publifhed.

In the fecond part, the firft effay, though it contains little or nothing new, will be found a proper introduction to the fubfequent ones.

The fecond effay, containing the theory of the trade-winds, was, as I conceived when it was printed off, original, but I find fince, that they are explained on the very fame principles, and in the fame manner, in the Philofophical Tran- for 1735, by *George Hadley*, Efq. F R. S.—See Martyn's Abridgment, Vol. 8, part 2, page 500.

The third effay, on the variation of the barometer, I fhould fuppofe will be confidered as having fome merit, it is new to myfelf, but as I am not well read in the modern productions on
the

fections; this will no doubt attract the attention of philofophers The reader will perceive all along, that I have fpoken of the difcovery therein contained as an original one , when I wrote the note at page 158, I had not feen the Abridgment of the Philofophical Tranfactions of the Royal Society, but I find from it that the learned and ingenious Dr. *Halley* formed an hypothefis to account for the *aurora borealis* by magnetifm; in the Abridgment by *Jones*, Vol. 4, part 2, we find, that the Doctor, after enumerating particulars of feveral appearances, conjectures that they are occafioned by the earth's magnetifm; and he endeavours to illuftrate the hypothefis by placing a *terella*, or fpherical magnet, with one of its poles upon an horizontal plane ftrewed with fteel filings, which being done, the filings form various ftraight lined and curvilinear figures, according as they are fituate near to or diftant from the magnetic pole; thefe he thinks are analogous to the beams of the *aurora borealis.* The *light* of the *aurora* he is pretty much at a lofs to account for, as electricity was then but imperfectly known.——If thefe hints of his had been purfued by others, the fact would undoubtedly before this have been eftablifhed, *that the beams of the* aurora borealis *are governed by the earth's magnetifm;* but inftead of this, philofophers have amufed themfelves and others with forming various other theories to account for the phenomena, moft of which are extravagant,

fections; this will no doubt attract the attention of philosophers. The reader will perceive all along, that I have spoken of the discovery therein contained as an original one; when I wrote the note at page 158, I had not seen the Abridgment of the Philosophical Transactions of the Royal Society; but I find from it that the learned and ingenious Dr. *Halley* formed an hypothesis to account for the *aurora borealis* by magnetism; in the Abridgment by *Jones*, Vol. 4, part 2, we find, that the Doctor, after enumerating particulars of several appearances, conjectures that they are occasioned by the earth's magnetism; and he endeavours to illustrate the hypothesis by placing a *terella*, or spherical magnet, with one of its poles upon an horizontal plane strewed with steel filings, which being done, the filings form various straight lined and curvilinear figures, according as they are situate near to or distant from the magnetic pole; these he thinks are analogous to the beams of the *aurora borealis*. The *light* of the *aurora* he is pretty much at a loss to account for, as electricity was then but imperfectly known.——If these hints of his had been pursued by others, the fact would undoubtedly before this have been established, *that the beams of the* aurora borealis *are governed by the earth's magnetism;* but instead of this, philosophers have amused themselves and others with forming various other theories to account for the phenomena, most of which are extravagant,

gant, not to fay ridiculous, M. *Mairan*'s *zodiacal light* not excepted. Notwithftanding what the learned Doctor has fuggefted, I prefume it will be allowed, that the above mentioned fact has not nitherto been afcertained, unlefs it be done in the following work.

Whilft I am blaming others for framing fanciful theories, perhaps the cenfure may be retorted upon myfelf.—The fourth fection of the effay in queftion, entitled the 'theory of the *aurora borealis*,' will perhaps be regarded by many as wild and chimerical; but the *facts* which I have endeavoured to afcertain, refpecting the *aurora*, will excufe me for a momentary indulgence of the ideas of a vifionary theorift, if they be confidered as fuch.

The appendix contains the refult of barometrical and other obfervations to determine the height of *Kendal* and *Kefwick* above the fea, more exactly than is ftated in the preliminary remarks to the obfervations on the barometer; alfo, an account of the heights of fome mountains in the neighbourhood of *Kefwick*; it concludes with a further illuftration of the doctrine of vapour, and an explanation of fome facts relating thereto, particularly thofe obferved in working the air-pump.

It will be fufficiently evident that I have not had a fuperabundant affiftance from books, in providing

able that the hiſtory of the progreſs of natural philoſophy could furniſh ——Dr *Halley* publiſhed in the Philoſophical Tranſactions, a theory of the trade-winds, which was quite inadequate, and immechanical, as will be ſhewn, and yet the ſame has been almoſt univerſally adopted; at leaſt I could name ſeveral modern productions of great repute in which it is found, and do not know of one that contains any other.   The ſame gentleman publiſhed, through the ſame channel, his thoughts on the cauſe of the *aurora borealis*, as mentioned above, which muſt then have appeared the moſt rational of any that could be ſuggeſted, and yet I do not find that any body has afterwards noticed it, except *Ama-nuenſis* (ſee page 159)   On the other hand, G. *Hadley*, Eſq. publiſhed in a ſubſequent volume of the ſaid Tranſactions, a rational and ſatisfactory explanation of the trade-winds , but where elſe ſhall we find it ?

Mancheſter, Sep 21, 1793.

ERRATA.

IN Part firſt, the ſections after the eighth are numbered wrong, they ſhould be corrected as follows :

Page 52, for Section *tenth*, read Section *ninth*.
Page 54, for Section *eleventh*, read Section *tenth*
Page 61, for Section *twelfth*, read Section *eleventh*

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CONTENTS.

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METEO-

METEOROLOGICAL

OBSERVATIONS AND ESSAYS.

PART FIRST,

OBSERVATIONS.

SECTION FIRST,

Of the Barometer.

THE barometer, or common weather-glass,
consists of a straight glass tube, above 31
inches long, and open at one end, that has been
filled with quickfilver, and afterwards inverted
into a bason of the fame fluid, by applying a
finger to the open end, so as to exclude all air
from entering the tube, in this cafe, the finger
being withdrawn, and the tube erected, the
quickfilver leaves the top of it, and finks so a
to ftand at the height of about 29 or 30 inches

B   above

above the furface of that in the bafon; it is then applied to a frame, with a fcale graduated fo as to mark at all times the height of the column, in inches and tenths, &c. The inftrument thus completed is called a barometer.—It is ufual now to blow a pretty capacious bulb at the open end of the tube, and then bend the tube a little above the bulb, fo that the bulb may ftand upright, leaving a little orifice in it to admit the quickfilver; then the tube being filled as before, upon being inverted, the column of quickfilver in the tube ftands at the height of 29 or 30 inches above the furface of that in the bulb, as in the former cafe.

The reafon of the fact may be explained thus: every body that fupports another, bears all its *weight;* therefore when the furface of any non-elaftic fluid is expofed to the air, it bears the weight of a column of air whofe bafe is equal to the faid furface, and its height that of the atmofphere, fuppofed to be 40 or 50 miles; now though air be a very light fubftance, being in its ufual ftate, at the earth's furface, about $\frac{1}{800}$th part of the weight of an equal quantity of water, yet fo prodigious a column of it as that above mentioned, has a very confiderable weight; moreover, it is a fundamental principle in hydroftatics, that the preffure upon the furface of a fluid muft be the fame on each part, or the fluid will not reft till that is the cafe; if, there-
fore,

fore, the preſſure be removed from any place of the ſurface, either wholly or in part, the fluid will yield in that place, and aſcend till the weight of the column of fluid above the ſurface, together with the preſſure upon the column, if any, are equal to the general preſſure upon the·fluid in every other part.——In the caſe of the barometer, there is a *vacuum* at the top of the column, and conſequently no preſſure upon its ſurface, ſo that the weight of the column alone balances the preſſure of the atmoſphere without, upon the ſurface of the fluid in the baſon. This *equilibrium*, between the mercurial column and column of air, is very clearly illuſtrated and confirmed by means of the air-pump; for, when a barometer is incloſed in a receiver, as the air is exhauſted, and its preſſure of conſequence decreaſed, the mercurial column deſcends proportionally. It appears then, that the weight of the air ſupports the mercury in the barometer, and that the weight of the mercurial column is equal to the weight of a like column of air extending to the top of the atmoſphere.———When the tube is bent at the bottom, and turned up, the ſame reaſoning, joined to the principle that fluids in bent tubes always riſe to the ſame height in each leg, when they are both open to the atmoſphere, will explain the fact in this caſe.

From theſe conſiderations, the weight of the whole atmoſphere may be readily found; for, it

is equal to the weight of a quantity of quick
filver fufficient to cover the whole furface of the
globe to the height of 30 inches nearly

The great weight and preffure above afcribed
to the atmofphere, and their effects, are affented
to by philofophers of the prefent age, without
fcruple, but people not much verfant in philo-
fophical enquiries admit them with reluctance;
they apprehend, that if bodies were preffed with
the force above mentioned, which amounts to
about 15lbs. avoirdupoife upon each fquare inch
of furface, the effect fhould be obvious, whereas
it is found that bodies of the flighteft texture
are unhurt by the atmofphere,—and the great
facility with which bodies are moved in the at-
mofphere, they conceive as another objection.—
Perhaps it may be fome help to thefe to obferve,
that the atmofphere preffes equally upon bodies
in every direction, and has therefore no tendency
to feparate their parts, and, as for the refiftance
which bodies meet with in moving through the
atmofphere, it is not proportionate to the *preffure*
of the atmofphere, but to its *denfity*, which
being very little, as has been obferved above,
the refiftance is fmall.

The barometer was invented in 1643, by
Torricelli, at Florence, in Italy.—The pheno-
menon foon attracted the notice of philofophers
of that age, and the more fo, as it feemed to
                                        prove

prove the exiftence of a *vacuum*, when the opinion of its non-exiftence was general, and the maxim that *nature abhors a vacuum*, was almoft unqueftioned. Had the quickfilver ftill continued to fill the tube when erected, the fact would have been accounted for on this imaginary principle, and have paffed without further notice. As it was, however, thofe who ftill adhered to the maxim were reduced to great difficulties, and forced to have recourfe to various unmeaning fubtilties, to get rid of the *vacuum*, whilft many began to queftion the truth of the maxim itfelf. At length it was clearly proved, from the inftance in queftion, and from other phenomena, that the maxim was contradictory to the laws of nature; the fufpenfion of the mercury in the barometer was attributed to its true caufe, the weight of the air, and the fpace at the top of the tube was afcertained to be nearly a perfect *vacuum*, or fpace void of matter. This difcovery, as it led to that of the air pump, and other important ones, is juftly regarded as one of the greateft in the laft century.

Torricelli, the inventer of the barometer, obferved, that if it was fuffered to ftand for a length of time, the height of the mercury in the tube was perpetually varying, though its whole range did not exceed 2 inches at that place, it was further noticed, that this variation feemed to have fome affinity to the weather, the quickfilver
being

being generally low in windy and rainy weather, and high in ferene and fettled weather, which circumftance procured the inftrument the name of *weather-glafs*. This diſcovery promifed to be of the utmoſt importance to mankind, by enabling them to forefee thoſe changes in the atmofphere, the knowledge of which was ſo intereſting to them, and the moſt ſanguine expectations were entertained on the ſubject. The experience of a century and a half has now been obtained, from which the barometer does not feem to be that infallible guide that it was once expected to be, though it is certainly a very uſeful inſtrument in this reſpect, in the hands of a judicious and ſkilful obſerver.——But of this more hereafter.

———————

SEVERAL ingenious contrivances have been uſed, by different perſons, to make barometers of a more ample range, in order to obſerve minute alterations of weight in the atmofphere; but all theſe are liable to ſuch objections as render the common upright one preferable.

Thoſe who wiſh to make barometrical obſervations, in order to compare them with others, ſhould be well aſſured of the accuracy of their inſtruments;——ſuch as incline to make their inſtruments themſelves would do well to attend to the following particulars,

That

That the tube be not lefs than one-eighth of an inch diameter within.

That the quickfilver be ftrained through a cloth, or rather through leather.

That the infide of the tube be perfectly dry, and the quickfilver dry when put into it.

If there be any moifture in the tube or quickfilver, it expands into an elaftic vapour when the preffure of the air is removed, and, afcending into the *vacuum*, depreffes the mercurial column, fometimes to the amount of one-quarter of an inch, or more, below its proper ftation. The criterion to difcover moifture is to apply the warm hand to the *vacuum*, and the mercury will fink confiderably; but it will not be affected if clear of moifture.—Alfo, if upon a gentle agitation of the barometer in the dark, there appear a light in the *vacuum*, it is a fign there is little or no moifture. If, upon a gentle inclination, the quickfilver rife to the top of the tube, and completely fill it, leaving no fpeck, it is clear of air.

The fcale in ftrictnefs ought not to be full inches, but fomething lefs, owing to the rifing and falling of the furface of the refervoir. If the tube have a bulb, then the area of the furface at the top of the column, divided by the fum of the

area's

areas of the top and refervoir, will give the part to be deducted; but if the tube be ftraight, then the whole area of the refervoir, leffened by the area of the glafs annulus, made by a horizontal fection of the erected tube, muft be ufed as the denominator of the fraction; hence, if the fraction be $\frac{1}{60}$, then the fcale of 3 inches muft be diminifhed by half a tenth.

PREVIOUS to the detail of obfervations, it will be proper to defcribe the fituation of the places of obfervation. ——The latitude of *London* is 51° 31′ N.—*Kendal* is fituate in lat. 54° 17′ N. long. 2° 46′ W. There lies an extenfive range of mountains from it in every direction, except to the fouth. Their height may be from 1 to 6 or 7 hundred yards* ; fome are near, but from the north to the eaft their diftance is 3, 4, or 5 miles. *St. George's Channel* bears SW. and the high water at fpring comes up the river to within 6 miles of the town, but low water is at a great diftance. The town may be 25 yards above the level of the fea.—*Kefwick* is fituate in lat. 54° 33′ N. long. 3° 3′ W.; it is well known to be in the centre of a mountainous country, and fome of the higheft mountains in the north of England are in its neighbourhood. It is 16 miles from the *Channel*, and perhaps about 45 yards above its level †.

The

* *Benfon-knot* is 310 yards above the level of the river; *Whinfel-beacon* is 500 yards above the fame; and *Kendal-fell* from 1 to 2 hundred yards.

† It may not be amifs to remind the young Tyro here, that the higher any place is above the level of the fea, the lower will the mean ftate of the barometer be at that place.

The obfervations at *Kendal* were made by the author, three times each day, namely, betwixt 6 and 8 o'clock in the morning, at noon, and at 8 or 10 in the evening.—Thofe at *Kefwick* were likewife made three times each day, the morning and noon obfervations about the fame time as at *Kendal*, but the evening obfervations were made at 4 or 5 in the winter, and 6 in the fummer; the obferver was Mr. *Crofthwaite*, a gentleman, who, befides his attention to meteorology, has been for feveral years paft affiduoufly furnifhing a *mufeum*, for the entertainment of the tourifts, at prefent confifting of a great variety of natural and artificial productions from every quarter of the globe, foffils, plants, &c. and he has alfo made accurate furveys of the lakes.

The obfervations at *London* are taken from the Philofophical Tranfactions of the Royal Society, being thofe made there by order of the prefident and council; they are made twice a day, namely at 7 A. M. (in December, January, and February at 8 A. M.) and at 2 P. M.

With refpect to the barometers at *Kendal* and *Kefwick*, they were both clear of air and moifture, and exhibited the electric light in the dark. The fcales were both *full* inches, and therefore the variations were fomewhat greater than the obfervations denote them.—About $\frac{1}{30}$ fhould have been allowed upon them.

In the following account we have given the mean ftate of the barometers, at the refpective places, for each month of the year, and likewife for the whole year, together with the higheft and loweft obfervations each month, and the time they took place; as alfo the direction of the wind, and its ftrength, at the time: the direction we have ufually referred to fome one of 8 equidiftant points of the compafs, and the ftrength is denoted by the figures 0, 1, 2, 3, and 4, refpectively, the firft marking a calm, or very gentle breeze, and the laft a hurricane.

C

The

The obfervations at *London* are only for 3 years, becaufe the later ones could not be procured; thofe at *Kendal* and *Kefwick* for 5 years, from 1788 to 1792, inclufive. To the end of thefe is added the mean monthly ftate of the barometer, found from the means of the 5 years, as alfo the mean upon the extremes, the former of which is corrected, on account of the variations of heat in the different months, by which the quickfilver in the barometer is contracted or dilated, though retaining the fame weight.——We have alfo fummed up the fpaces defcribed by the quickfilver each month, noted the number of changes from afcent to defcent, and the contrary, and found their amount for the year.

By the *mean ftate*, applied to obfervations, is to be underftood the fum of all the particular obfervations divided by their number.

The upper part of the following tables, having no abbreviations, is fufficiently explicit; and in the under part, which contains the days in the feveral months on which the higheft and loweft obfervations were taken, and the winds at thofe times, we have ufed H, for higheft, L, for loweft, m, for morning, n, for noon, and nt, for night.

N. B. *Kendal* bears N. 30° W. from *London*, diftant nearly 226 Englifh miles, meafured on a great circle of the earth; *Kefwick* bears N. 35° W. from *Kendal*, diftant 22 Englifh miles, meafured on a great circle.

1788.

1788.

	LONDON.			KENDAL.			KESWICK.		
	Mean	higheſt	loweſt	Mean	higheſt	loweſt	Mean	higheſt	loweſt
Jan.	29.97	30.70	28.89	29.87	30.56	28.38	29.82	30.56	28.35
Feb.	29.68	30.21	28.65	29.47	30.22	28.65	29.42	30.17	28.61
March	29.68	30.08	29.32	29.56	30.09	29.15	29.51	30.07	29.12
April	30.07	30.48	29.50	29.95	30.41	28.97	29.89	30.36	28.92
May	30.04	30.34	29.58	30.02	30.41	29.47	29.94	30.32	29.37
June	29.94	30.28	29.49	29.94	30.31	29.50	29.89	30.26	29.46
July	29.99	30.22	29.73	29.82	30.12	29.47	29.76	30.12	29.40
Aug.	29.95	30.45	29.22	29.83	30.37	29.19	29.77	30.37	29.14
Sep.	29.86	30.25	29.37	29.74	30.16	29.28	29.67	30.09	29.20
Oct.	30.32	30.55	29.64	30.07	30.62	29.50	30.02	30.63	29.43
Nov.	30.11	30.50	29.61	29.98	30.34	29.22	29.92	30.32	29.20
Dec.	29.92	30.33	29.50	29.92	30.28	29.53	29.90	30.23	29.50
Inches	29.96 annual mean			29.85 annual mean			29.79 annual mean		

		LONDON		KENDAL		KESWICK	
Jan.	H	16 n	WNW 1	16 n & nt	W 1	16 n & nt	W 2
	L	3 n	S 2	3 n	S 2	4 m	W 1
Feb.	H	7 m & n	NE 1 (a)	7 n	SE 0	7 n	calm
	L	21 n	SSE 1	21 n & nt	NE 2 (b)	21 nt	SE 1
Mar.	H	3 n	E 2 (c)	3 n & nt	NE 1	3 n & nt	W 0
	L	23 m	N 2	1 m	SE 1	1 m	SW 0
Apr.	H	9 m	WNW 1	9 n	calm	9 n	S 2
	L	3 n	W 2	3 n	NW 3	3 n	W 3
May	H	3 m	ENE 2	3 all day	NE 2	3 m & n	E 2
	L	29 m	SW 1	9 n	SW 3	9 n	SW 3
June	H	5 n	W 1	9 all day	NE 1	9 n & nt	NE 1
	L	27 n	S 1	26 nt & 27 m	NW 0	27 m	NW 0
July	H	21 n	NW 1 (d)	21 n	NW 0	21 n	W 1
	L	5 n	SSW 1	16 m	SW 1	16 m	SW 1
Aug.	H	2 m	N 1	2 m	NW 1 (e)	2 n	NW 1
	L	14 m	SW 1	14 m	W 0	14 m	W 1
Sep.	H	12 m	ESE 1	11 nt	NW 0	11 nt	NW 0
	L	21 m	calm	29 n	W 2	29 n	W 2
Oct.	H	8 m	SEbS 2 (f)	8 n & nt	NE 0	8 n & nt	E 0
	L	16 n	W 1	16 m & n	SW 0	16 m & n	W 1
Nov.	H	1 m	E 1	1 m	SW 0	1 m	SE 0 (g)
	L	4 m	SW 2	3 nt	SW 2	3 nt	SW 3
Dec.	H	30 m	E 1	28 nt	N 0	28 nt	NE 0
	L	14 n	NE 1	31 nt	calm	31 nt	calm

(a) And 12 m. SW 1. (b) And 22 m. NE 2. (c) And 11 n. ENE 1.
(d) And 31 m. SW 1. (e) And 2 n. SE. 1. (f) And 8 n. NE 2.
(g) And 16 m. NE 0.

1789.

	LONDON			KENDAL			KESWICK		
	Mean	highest	lowest	Mean	highest	lowest	Mean	highest	lowest
Jan.	29.72	30.75	28.58	29.59	30.75	28.12	29.51	30.72	28.09
Feb.	29.70	30.34	28.65	29.52	30.19	28.50	29.44	30.20	28.43
March	29.72	30.13	28.94	29.71	30.12	28.87	29.59	30.13	28.71
April	29.77	30.18	29.10	29.64	30.09	28.94	39.51	29.98	28.77
May	29.88	30.27	29.57	29.77	30.19	29.37	29.66	30.12	29.23
June	29.84	30.23	29.40	29.77	30.20	29.25	29.66	30.12	29.14
July	29.85	30.09	29.54	29.74	30.00	29.50	29.63	29.88	29.40
Aug.	30.06	30.33	29.70	29.99	30.32	29.62	29.88	30.23	29.46
Sept.	29.88	30.38	29.30	29.75	30.25	29.25	29.64	30.15	29.17
Oct.	29.52	30.29	29.00	29.56	30.30	28.59	29.46	30.20	28.48
Nov.	29.70	30.46	28.72	29.60	30.34	28.69	29.48	30.27	28.60
Dec.	29.86	30.56	28.88	29.63	30.41	28.72	29.48	30.32	28.57
Inches	29.79	annual mean		29.69	annual mean		29.58	annual mean	

Month		LONDON		KENDAL		KESWICK	
Jan.	H	5 n	ENE 1	5 nt	N 0	5 n & nt	E 0
	L	18 n	S 2	18 n	S 3	18 n	SW 2
Feb.	H	17 m	SW 1	16 m	calm	16 m	NW 1
	L	25 n	SW 2	25 n & nt	SW 1	25 n & nt	NE 1 N 2
Mar.	H	3 m	NNE 1	6 m & n	NE 1	6 m & n	NE 1 N 1
	L	13 n	W 1	13 m & n	NE 2 E 3	13 n	SE 1
Apr.	H	21 m	WSW 1	9 nt	SW 0	9 all day	E 0
	L	3 m	SW 1	26 n	SW 3 (a)	26 m & n	W 1 (b)
May	H	19 n	W 2	11 n & nt	SW 0	11 nt	W 1
	L	31 n	SW 1	17 nt	SW 2	17 nt	S 2
June	H	13 m & n	ENE 1	13 n & nt	N 0	13 n & nt	S 1
	L	4 m	WSW 2 (c)	22 m	SW 0	22 m	E 0 (d)
July	H	1 m	W 1	28 & 30 nt	calm	28 & 30 nt	W 1 S 0
	L	13 m & n	ESE 1	17 n	W 1	17 n	S 0
Aug.	H	18 m	NNW 1	17 m	NE 0	17 all day	NE 0
	L	21 n	W 1 (e)	22 & 31 nt	calm	31 nt	calm
Sept.	H	12 n	WNW 1	12 n	SW 1	12 n	NW 1
	L	19 n	WNW 1	19 n	N 0	19 nt	NW 0
Oct.	H	27 n	NNW 1	27 nt	NE 1	27 nt	N 1 (f)
	L	6 m	W 2	1 n	SW 3	1 m	S 2
Nov.	H	27 m	W 1	27 all day	N 0	27 all day	NW 0
	L	7 m	N 1	6 n & nt	NE 2	6 nt	N 3
Dec.	H	9 m & n	W 1	9 all day	SW 0	9 nt	W 1
	L	15 m	W 2	15 n	W 1	15 n	SW 2

(a) And 27 m. SE 1.   (b) And 27 m. SE 0.   (c) And 4 n. also 22 n. S 2.
(d) And 4 m & n. W 1.   (e) And 22 m. W 1. also 31 m & n. SSE 1.
(f) And 28 m. NW 0.

1790.

	LONDON			KENDAL			KESWICK		
	Mean	highest	lowest	Mean	highest	lowest	Mean	highest	lowest
Jan.	30.07	30.47	29.27	29.91	30.34	28.65	29.89	30.36	28.64
Feb.	30.25	30.62	29.88	30.06	30.41	29.47	30.02	30.41	29.40
March	30.26	30.65	29.83	30.18	30.59	29.57	30.15	30.59	29.48
April	29.86	30.30	29.38	29.85	30.28	29.28	29.81	30.28	29.19
May	29.90	30.14	29.50	29.85	30.28	29.25	29.82	30.28	29.19
June	30.03	30.35	29.49	29.89	30.25	29.31	29.87	30.28	29.22
July	29.84	30.20	29.29	29.72	30.09	29.34	29.68	30.15	29.28
Aug.	29.97	30.16	29.64	29.81	30.03	29.47	29.77	30.05	29.42
Sept.	30.00	33.42	29.31	29.87	30.34	29.25	29.84	30.34	29.14
Oct.	29.89	30.40	29.62	29.80	30.28	29.22	29.75	33.26	29.11
Nov.	29.81	30.40	29.02	29.75	30.34	28.97	29.70	30.28	28.90
Dec.	29.88	30.38	28.80	29.70	30.34	28.84	29.67	30.31	28.74
Inches	29.98 annual mean			29.87 annual mean			29.83 annual mean		

		LONDON		KENDAL		KESWICK	
Jan.	H	7 n	WNW 1	7 n & nt	calm	7 n & nt E 1, S 0	
	L	28 n	SW 2	28 nt	SW 2	28 nt	W 0
Feb.	H	4 n	W 1	4 n & nt	W 1	6 n	W 1
	L	26 n	SW 2	26 n	SW 2	26 m	SW 4
Mar.	H	16 m	NNE 1	15 m & n	NE 0	15 n	SE 0
	L	24 m	E 1	10 m	W 2	10m&n SW 4 W 3	
Apr.	H	3 m	N 2	2 all day NE 1 (a)		2 n	SE 1 (b)
	L	11 m	NE 2	30 m	S 2	30 m	S 1
May	H	13 m	NE 2	12 n & nt NE 1 (c)		12 allday NE 2 (d)	
	L	2 m	SSW 2	2 m	SW 1	2 m	NE 0
June	H	21 m & n WSW 1		14 nt	NE 0 (e)	14nt 15m W 0 E 0	
	L	9 n	SSW 2	9 nt	SW 0	9 nt	calm
July	H	7 n	NW 1 (f)	7 all day	calm	7n&nt S 1 NW 1	
	L	5 n	W 1	13 n & nt W 1 (g)		20m&nt SW 3 W 2	
Aug.	H	18 m	WNW 1	11 nt & 12 m W 0		11 all d. NW 0 (h)	
	L	26 m	———	3 n	SW 0	3 m & n SW 1	
Sep.	H	26 n	N 1 (i)	26 n	N 0	26 n	NW 0
	L	3 n	W 2	3 m	W 0	20 nt	SW 3
Oct.	H	16 n	E 1	16 n & nt	W 0	16n&nt W 0 SE 0	
	L	23 n	E 1	12 nt	W 2	12 n	S 3
Nov.	H	28 m	N 1	14 m	NE 1 (k)	14, 15 all day (l)	
	L	21 m	SW 2	19 nt	N 0	19 all day S 0 E 0	
Dec.	H	6 m	NW 1	6 n & nt	NE 0	6 n	calm
	L	18 m	W 2	15 m	SW 4	15 m	WSW 4

(a) And 3 all day E 1. (b) And 3 all day NW 1. (c) And 13 m. NE 1.
(d) And 13 n. NE 2. (e) And 15 m & n. NE 0. (f) And 17 m & n.
NW 1. also 26 m. WSW 1. (g) And 20 m & n. SW 2. (h) And 12 all day
NW 0. also 14 n. & 18 m. SW 0. (i) And 26 m. WNW 1.
(k) And 13 nt & 27 nt. NE 1. (l) E 2. SE 0.

1791.

	KENDAL			KESWICK		
	Mean	highest	lowest	Mean	highest	lowest
Jan.	29.33	30.22	28.40	29.23	30.17	28.31
Feb.	29.83	30.47	29.00	29.77	30.42	28.85
March	30.06	30.59	28.88	30.01	30.51	28.82
April	29.72	30.12	28.97	29.66	30.11	28.91
May	29.94	30.37	29.22	29.90	30.37	29.08
June	29.89	30.19	29.50	29.86	30.17	29.40
July	29.76	30.22	29.22	29.71	30.19	29.11
August	29.96	30.47	29.47	29.91	30.48	29.29
Sept.	30.04	30.34	29.31	30.01	30.31	29.19
Octo.	29.62	30.47	28.56	29.55	30.46	28.45
Nov.	29.58	30.15	28.66	29.51	30.11	28.56
Dec.	29.51	30.28	28.84	29.44	30.19	28.68
Inches	29.77 annual mean			29.71 annual mean		

		KENDAL		KESWICK	
Jan.	H	24 m	W 2	24 m and n	WSW 3 & 4
	L	20 m	E 1	20 m	E 2
Feb.	H	4 nt	calm	4 nt	calm
	L	18 n	NW 1	18 m	W 2
Mar.	H	8 m and n	SW 1, NE 0	8 m and n	E 1
	L	20 nt, 21 m	SW 2	20 nt, 21 m SW & W	3
Apr.	H	29 nt, 30 m	NE 1	29 nt, 30 m NW&NE	2
	L	23 m and n	SW 1	23 m and n NW & N	1
May	H	28 nt	NE 0	28 n	E 1
	L	19 m	W 3	19 m	WSW 4
June	H	7 m	NE 0	7 m	W 1
	L	30 all day	SW 1	30 n and nt SE 1, SW 0	
July	H	15 m and n	NE 0	15 nt	calm
	L	4 n	SW 3	4 m and n	WSW 3
Aug.	H	20 m	NE 0	19 nt, 20 m	calm
	L	28 m	W 1	28 m	W 0
Sep.	H	26 m	NE 0	26 m	NE 0
	L	4 m	SW 0	4 m	SW 1
Oct.	H	29 all day	NE 1	29 m and n	NE 2
	L	21 m	SW 1	21 m	SE 1
Nov.	H	26 nt	S 0	26 nt	SW 2
	L	16 m	SW 1	16 m	SW 1
Dec.	H	17 m and n	NE 0	17 n	NE 0
	L	13 m and n	SW 1	13 m	WSW 3

1792.

	KENDAL.			KESWICK.		
	Mean	higheft	loweft	Mean	higheft	loweft
Jan.	29.60	30.37	28.87	29.53	30.34	28.65
Feb.	29.87	30.47	29.34	29.82	30.43	29.25
Mar.	29.60	30.41	29.00	29.51	30.40	28.91
April	29.80	30.28	29.16	29.73	30.23	29.02
May	29.88	30.34	29.03	29.82	30.28	28.79
June	29.86	30.37	29.37	29.82	30.39	29.28
July	29.80	30.09	29.47	29.74	30.06	29.37
Auguft	29.86	30.22	29.12	29.81	30.22	29.02
Sept.	29.65	30.22	29.06	29.59	30.17	28.91
Octo.	29.73	30.47	29.09	29.67	30.45	28.94
Nov.	29.90	30.37	29.09	29.82	30.31	28.96
Dec.	29.71	30.28	28.90	29.62	30.20	28.71
Inches	29.77 annual mean			29.71 annual mean		

		KENDAL		KESWICK	
Jan.	H	5 all day	calm	5 all day	calm
	L	16 m	SW 0	15 nt	S 1
Feb.	H	16 nt, 17 m	NE 1	17 m and n	NE 0
	L	1 m	SW 1	1 m	SW 0
Mar.	H	12 m and n	NE 1	12 m	NE 0
	L	4 n	SW 0	4 n	W 0
Apr.	H	29 m	SW 0	29 m and n	calm
	L	4 nt	SW 1	4 nt	calm
May	H	5 nt, 6m	NE 1	5 nt, 6m	N 2, NE 1
	L	29 m and n	SE 3	29 m	SE 4
June	H	3 all day	N 1	3 n and nt	NE 1, N 0
	L	11 m and n	SW 1	11 m	calm
July	H	15 n, 31 nt	W 0	15 n, 31 nt	SW 1, SE 1
	L	27 m and n	SW 1	27 m	calm
Aug.	H	1 m & n 29 all d.	NE 0 & 1	1 n, 29 n	NE 0
	L	23 m	SW 1	23 m	SW 1
Sep.	H	16 m	SW 0	15 nt	SW 0
	L	22 m	SW 0	21 nt	SW 0
Oɛt.	H	24 nt	NE 0	24 nt	N 1
	L	14 n, 15 m	SW 1	14 n and nt	S 1
Nov.	H	24 nt	NE 0	24 nt	calm
	L	14 n and nt	SE 2	14 n and nt	SE 1
Dec.	H	2 nt	calm	2 nt	calm
	L	6 nt	SW 3	6 nt	SW 4

GENERAL OBSERVATION.

It will be ſeen from the above accounts, that the baro-
meter is generally higheſt and loweſt about the ſame time
at all the three places; and if the obſervations had been all
taken at the ſame hour, it would have been more generally
the caſe.—Whenever the barometer happens to be at the
monthly extreme at one place, and not at another, I find it
is always near it at the other; the greateſt differences in this
reſpect ſeem to take place about the lower extreme, and to
be occaſioned by rain,—thus, when it happens to be exceſ-
ſively heavy rain at one place, and not at another, the baro-
meter is relatively loweſt where the rain falls.

Mean ſtate of the barometer at Kendal *and* Keſwick, *for the
whole 5 years, for each particular month of the year; together
with the means upon the extremes of high and low, and the
mean monthly range.*

	KENDAL.				KESWICK.			
	Mean*	higheſt	loweſt	range	Mean*	higheſt	loweſt	range
January	29.68	30.45	28.49	1.96	29.62	30.43	28.41	2.02
February	29.77	30.35	28.99	1.36	29.71	30.33	28.91	1.42
March	29.84	30.36	29.09	1.27	29.77	30.34	29.01	1.33
April	29.79	30.23	29.06	1.17	29.72	30.19	28.96	1.23
May	29.88	30.32	29.27	1.05	29.82	30.27	29.13	1.14
June	29.85	30.26	29.38	.88	29.80	30.24	29.30	.94
July	29.74	30.10	29.40	.70	29.68	30.08	29.31	.77
Auguſt	29.86	30.28	29.37	.91	29.80	30.27	29.27	1.00
September	29.80	30.26	29.23	1.03	29.74	30.21	29.12	1.09
October	29.76	30.43	28.99	1.44	29.69	30.40	28.88	1.52
November	29.78	30.31	28.23	1.38	29.70	30.26	28.85	1.41
December	29.72	30 32	28.97	1.35	29.65	30.25	28.84	1.41
Inches	29.79	30.31	29.20	1.21	29.72	30.27	29.00	1.27

The

* The means in this column are corrected, on account of the expanſion
of the mercury, by heat; the correction is made by increaſing the height
in the colder months, and leſſening it in the warmer months, proportionally
to the defect or exceſs of temperature, relative to the mean; it never
exceeds .03 of an inch.

'The mean monthly range at *London*, upon an average of the 3 years we have given, is, Jan 1 73 inches, Feb 1 33, March 0 96, April 0 99, May 0 70, June 0.83, July 0 65, Aug 0 79, Sept 1 02, Oct 0 99, Nov 1 34, Dec 1 36. Mean range 1 06 inches.

A Table of the mean fpaces defcribed by the mercury each month, determined by fumming up the feveral fmall fpaces afcended and defcended, alfo the mean number of charges from afcent to defcent, and the contrary, each month, it being reckoned a charge when the fpace defcribed is upwards of 0 3 of an inch —The means are for 5 years, at Kendal *and* Ketwick.

	KENDAL		KESWICK.	
	Mean fpaces defcribed by the mercury, in inches	Mean number of changes, &c	Mean fpaces defcribed by the mercury, inches.	Mean number of changes, &c
January	9 97	23	10.15	20
February	7 57	21	7.90	20
March	6 64	19	7.30	21
April	6.06	17	6 15	20
May	5 47	19	5.65	19
June	3 89	16	4 25	16
July	4 98	21	5 20	22
Auguft	4 32	18	4.93	19
September	5 87	19	6 59	20
October	6.30	18	6 24	20
November	7.36	18	7 69	20
December	10 08	22	9.95	24
Ann. fpace	78 51	231	82 00	241

SECTION SECOND.

Of the Thermometer.

THE next important inftrument in meteor-
ology is the thermometer : by which the
temperature, or degree of heat, of the air and
other bodies, is determined. An inftrument
under this character was invented prior to the
barometer, but never brought to a tolerable de-
gree of perfection till the prefent century.

Philofophers are generally perfuaded, that the
fenfations of *heat* and *cold* are occafioned by the
prefence or abfence, in degree, of a certain prin-
ciple or quality denominated *fire*, or *heat*,—thus,
when any fubftance feels cold, it is concluded
the principle of heat is not fo abundant in that
fubftance as in the hand, and if it feel hot, then
more abundant. It is moft probable, that all
fubftances whatever contain more or lefs of this
principle. Refpecting the nature of the prin-
ciple, however, there is a diverfity of fentiment :
fome fuppofing it a *fubftance*, others a *quality*,
or property of fubftance. *Boerhaave*, followed
by moft of the moderns, is of the former opi-
nion, *Newton*, with fome others, are of the
latter, thefe conceive heat to confift in an in-
ternal vibratory motion of the particles of bodies.
Whatever

Whatever doubts may be entertained respecting the *cause* of heat, many of its effects are clearly ascertained : in treating of those effects it is expedient to adapt our language to one or other of the suppositions respecting the nature of their cause; and as nothing has yet appeared to render the common mode of expression unphilosophical, we shall therefore speak of fire as a *substance*, under the denomination of fire, or heat.

One universal effect of fire is its expanding or enlarging those bodies into which it enters; which bodies subside again when the fire is withdrawn. *Solids* are least expanded by it; *inelastic fluids*, as water, spirits, &c. are more expanded; and *elastic fluids*, as air, most of all. Hence, if a glass tube of very small bore, and a large bulb at the end, be filled with any liquid so as it may rise into the stem, and heat be applied to the bulb, the liquor will rise in the tube, and it is obvious to infer, that the larger the bulb and the smaller the bore of the tube, all other circumstances being the same, the greater will be the ascent for a given variation of heat : such an instrument, when applied to a frame properly graduated, is called a *thermometer*. Different fluids have been occasionally used for thermometers, but none is found to answer so well, in all respects, as quicksilver.

Boiling

Boiling water is of a conftant and uniform temperature at all times and places, provided the barometer be at a certain height, and a mixture of pounded ice, or fnow, and water is likewife of an uniform temperature　Hence, we are favoured with the means of finding two fufficiently diftant points upon the thermometric fcale, without the neceffity of another thermometer, thefe are called the *boiling* and *freezing points*, and are marked with 212° and 32° refpectively, upon the common fcale, or that of *Fahrenheit*, the boiling point being found when the fcale ftands at 30 inches. The fcale is divided into equal parts, and extended above and below thefe points, *ad libitum,* when the degrees go below 0, they are counted from it, and termed *negative,* merely for diftinction *. At 55° the word *temperate* is ufually placed upon the fcale, and *fummer heat* at 75°, 98° denotes the ufual heat of the human blood ; 112° the heat of the blood fometimes in an inflammatory fever, and at 175° fpirits boil ; quickfilver itfelf boils at about 600°.

Reaumur's fcale, ufed by fome philofophers on the continent, marks the freezing point with 0°, and the boiling point with 80°.

THE

* The Tyro will pleafe to obferve, that the term 0°, does not imply a total deprivation of fire, it is a mere arbitrary term, and there would have been no lefs propriety in calling it 100°, or 1000°, than 0°.

THE following is the refult of obfervations on the ther-
mometer, taken three times a day, at *Kendal* and *Kefwick*,
from 1788 to 1792, inclufive. The morning obfervations
were taken between 6 and 8 o'clock; the mid-day obferva-
tions about 12 or 1; the night obfervations at *Kendal* about
9 or 10, but at *Kefwick* at 6 in fummer, and 4 in winter;
this circumftance makes the mean temperature of *Kefwick*
too high, when compared with that of *Kendal*, which ought
to be noticed in the comparifon.

The fituation of the thermometers too, is another par-
ticular that fhould be adverted to;—that at *Kendal* was
without, in a garden, under the fhade of a pretty large
goofeberry tree, facing the north: the garden is open to
the country in the north, and has houfes at the diftance of
8 or 10 yards to the fouth. The thermometer at *Kefwick*
is fituate near, but not in contact with, the wall and window
of a houfe facing the north, which is open to the country;
it is about 6 yards above the ground; the fun never fhines
on it in winter, and only a few weeks in fummer, and that
early in the morning, long before the obfervation is taken.

From thefe accounts it is obvious to infer, that the ther-
mometer at *Kefwick* will not be liable to the *extremes* of heat
and cold, owing to the influence of the adjoining wall;
whereas that at *Kendal* is perhaps liable to too great an ex-
treme of heat, occafionally, owing to the reflection from the
ground, though the fun never fhines upon the frame for an
hour at leaft before any obfervation is taken.

The following tables, it is prefumed, will be fufficiently
explicit; we have given a table each year, containing the
days on which the extremes of heat and cold happened at
each place, as with the barometer.

AT

AT KENDAL, 1788.

	Morning.			Noon.			Night.			month.
	Mean	high.	low.	Mean	high.	low.	Mean	high.	low.	means.
	°	°	°	°	°	°	°	°	°	°
Jan.	37.7	46	20	41	47	31	38 3	46	24	39
Feb.	36.3	44	28	41	47	31	37.7	46	28	38.3
March	33.9	46	18	40.3	50	31	36.3	50	21	36 8
April	43.8	49	32	49.5	69	39	45.8	55	34	46.3
May	48.7	61	39	61.8	80	43	48 6	61	38	53 0
June	55.0	60	47	66.4	80	57	52 5	60	45	57-3
July	55.0	62	49	61 0	68	53	54.4	62	47	56.8
Aug.	53.5	58	47	63 7	74	57	54.2	60	49	57. 1
Sep.	49.5	60	35	59 4	70	50	51.8	62	43	53.6
Oct.	41.5	55	28	52 6	58	47	43.1	57	30	45.7
Nov.	38.3	50	27	44 5	52	33	39.3	52	28	40.7
Dec.	26	40	10	33.5	46	23	27.6	40	18	29
an. m.	43.1			51.2			44.1			46.1

AT KESWICK, 1788.

(The obſervations on the thermometer at Keſwick *this year were not complete till May.)*

	Morning.			Noon.			Night.			month.
	Mean	high.	low.	Mean	high.	low	Mean	high.	low.	means.
	°	°	°	°	°	°	°	°	°	°
May	54.8	71	41	61	77	41	58.9	72	39	58.2
June	57.6	67	52	62.3	77	56	60 5	75	51	60.5
July	58.6	68	52	61.7	70	58	60.3	64	56	60.2
Aug.	58.5	62	52	63.2	75	56	61.6	72	53	61.1
Sep.	54.6	64	46	58.3	68	48	55.9	66	48	56.3
Oct.	44.4	57	28	50.5	59	41	46.8	57	34	47.2
Nov.	42.1	52	28	44.2	52	32	42.5	54	28	42.9
Dec.	26.2	43	8	30.2	44	18	28.5	41	17	28.3

1788.

1788.

		Morning.		Noon.		Night.	
		Kendal.	Keswick.	Kendal.	Keswick.	Kendal.	Keswick.
Jan.	H	24th day		24th & 27th days		26th day	
	L	15		15		24	
Feb.	H	15		15		14	
	L	2		2		10	
Mar.	H	30		22, 30		30	
	L	7, 11		13		7, 8	
Apr.	H	11, 12		30		30	
	L	4, 5		4		4	
May	H	28	26	26	26, 27	27	25, 27
	L	6	29	29	29	10	29
June	H	18	16, 17	21	17	17, 18, 20	17
	L	1, 8	12, 20, 28	19	27, 28, 30	9	19
July	H	12	13	12	13	11	12, 13, 30
	L	28	5	10	7, 8, 22	8	25
Aug.	H	1, 13	3, 10, 13, 14	4	4	12	3, 4
	L	18	27	23	26	19	24
Sep.	H	5	8	4	4, 8	4	4
	L	15	21	29	21	14	21
Oct.	H	2	2	2, 5, 22	2, 22	2	22
	L	19	18	18, 19, 20	18	18	18
Nov.	H	11, 12	11	3, 11	2, 3, 11, 12	12	3, 11
	L	16	15	16	15	15	26
Dec.	H	24	25	24	24	24	24
	L	16	8, 16	15, 16	15, 17, 28		17, 28

AT KENDAL, 1789.

	Morning.			Noon.			Night.			month means.
	Mean	high.	low.	Mean	high.	low.	Mean	high.	low.	
	°	°	°	°	°	°	°	°	°	°
Jan.	30.8	47	4	36	50	19	32	47	5	33
Feb.	37.7	46	28	42.2	47	32	37.7	46	30	39.2
March	30.5	37	22	41.4	48	31	32	37	25	34.6
April	39.4	47	25	49.8	60	36	40.5	49	31	43.2
May	45.8	55	41	60	70	51	49.4	57	38	52.7
June	51.5	60	38	63.6	79	53	51.6	60	45	55.6
July	54	62	41	64.8	74	54	54.4	62	49	57.7
August	53.7	62	42	69.4	79	60	56	62	50	59.7
Sept.	49.8	57	32	58.4	67	50	49.2	58	37	52.5
Octo.	42.4	55	27	51	57	39	43.4	55	29	45.6
Nov.	35	44	20	42.5	51	31	35.7	45	23	37.7
Dec.	40.6	48	25	43.4	49	35	40.9	49	29	41.6
ann. ms.	42.8			51.9			43.6			46.1

AT KESWICK, 1789.

	Morning			Noon			Night			month. means.
	Mean	high.	low.	Mean	high.	low.	Mean	high.	low.	
	°	°	°	°	°	°	°	°	°	
Jan.	33	49	7	34.9	50	20	33.8	50	16	33.9
Feb.	37.7	46	29	40.4	48	34	36.7	47	30	38.9
Mar.	29.7	39	23	36.4	46	29	33.2	40	28	33.1
April	41.6	49	28	45.9	56	33	44.1	51	29	43.9
May	50.9	60	41	56.7	68	45	54.	68	41	53.9
June	55.3	69	44	59.	73	49	55.8	69	47	56.7
July	58.2	66	49	62.4	71	51	60.2	70	50	60.3
August	59.6	67	51	64.9	74	67	62.9	71	51	62.5
Sept.	52.7	61	41	56.4	65	46	54.8	64	46	54.6
Octo.	44.2	52	26	48.9	56	36	46.9	57	32	46.7
Nov.	37	45	23	41.2	48	31	39.1	48	28	39.1
Dec.	42.5	49	31	43.4	49	34	42.2	52	34	42.7
ann.ms.	45.2			49.2			47.1			47.2

1789.

		Morning		Noon		Night	
		Kendal.	Keswick.	Kendal.	Keswick.	Kendal.	Keswick.
Jan.	H	30	30	31	30	26	30
	L	12	12	5, 12	7	5	11, 12
Feb.	H	15	1, 15	1, 15, 18, 24	15	14	1
	L	12	27	4	11, 12, 16	7	11
Mar.	H	20, 21	13	21	21	2, 28	2
	L	24	8, 17	13	7	11	7, 10, 13
Apr.	H	21	20, 21	30	30	16	16, 30
	L	12	4	7	3	4	3
May	H	24, 25, 28	26, 28	13	13	13	13
	L	1, 11	2, 4	5	18	3	3
June	H	18	18	17	17	17	13, 16
	L	2	26	6, 26	6, 28	7, 25	27
July	H	4	3	4	4	4	3
	L	24	23	22	22	23	22
Aug.	H	5	4	13	18	4	18
	L	23	1	7, 22	6	22	30
Sep.	H	1, 4, 9	1	5	6	3, 10	1
	L	17	17	15, 19	19	18	16
Oct.	H	21	21	23	23	20	20
	L	26	31	31	31	31	31
Nov.	H	14	2, 14	3	2	1	10
	L	27	26	27	26	26, 27, 28	26
Dec.	H	6	22	6, 27	6, 7	23, 27	7
	L	1	16	16	16	25	17

AT KENDAL, 1790.

	Morning.			Noon.			Night.			month.
	Mean	high.	low.	Mean	high.	low.	Mean	high.	low.	means.
	°	°	°	°	°	°	°	°	°	°
Jan.	36.3	47	22	40	49	31	37.2	47	24	37.8
Feb.	39.8	47	25	46.2	54	39	41.2	47	28	42.4
March	35.5	45	24	50.7	58	39	38.1	46	29	41.4
April	37.5	46	23	50.1	58	40	37.5	47	28	41.7
May	48.5	55	38	59.8	71	51	48	58	43	52.1
June	52.4	62	43	61.7	76	53	53.4	62	46	55.8
July	51.6	58	41	60.9	67	54	53.2	59	47	55.2
Aug.	52.5	60	38	61.4	71	56	55	63	48	56.3
Sep.	47	56	33	56.7	68	51	49.1	52	42	50.9
Oct.	43.3	55	28	54.3	65	47	45.4	58	33	47.6
Nov.	37.8	50	24	44.1	53	34	37.6	48	21	39.8
Dec.	34.3	46	6	39	49	22	34.9	47	22	36.1
an. m.	43.0			52.1			44.2			46.4

AT KESWICK, 1790.

	Morning.			Noon.			Night.			month.
	Mean	high.	low.	Mean	high.	low.	Mean	high.	low.	means.
	°	°	°	°	°	°	°	°	°	°
Jan.	36.4	48	29	39.7	50	30	38.7	50	32	38.6
Feb.	43.3	49	32	45.4	51	39	43.8	49	35	44.2
March	39.3	49	31	47.7	52	38	44.3	50	38	43.8
April	39	49	31	44.8	54	38	41.2	49	32	41.7
May	50.8	58	45	55.5	64	46	52.9	63	45	53.1
June	55	68	47	58.7	71	49	57.6	70	49	57.1
July	53.9	59	48	59.5	65	52	56.5	63	51	56.6
Aug.	54.8	61	51	60.5	69	55	57.5	64	51	57.6
Sep.	49.2	56	41	53.7	62	43	50.8	62	43	51.2
Oct.	46.5	59	35	52.1	62	44	48.8	59	37	49.1
Nov.	37.6	49	25	41.6	50	30	39.9	50	26	39.7
Dec.	35.7	47	18	37.9	49	27	36.8	47	28	36.8
an. m.	45.1			49.8			47.4			47.4

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1790.

		Morning.		Noon.		Night.	
		Kendal.	Keswick.	Kendal.	Keswick.	Kendal.	Keswick.
Jan.	H	3, 12	14	3	12	12	12
	L	21	9, 15, 21, 30	15, 17	15	20	20. 25
Feb.	H	25	26	28	22	24	22, 25
	L	21	1	1	10	20	10
Mar.	H	2, 12	2	28, 30	20, 22, 30	11	18
	L	17	4, 15, 17, 18	5, 10	10	15, 16	5, 15
Apr.	H	23, 27	29	19	23	22	28
	L	17	11, 13	16	13	14	12, 13, 14
May	H	30, 31	30	29, 31	31	29	16
	L	14	19, 21	4, 27	2	3	5
June	H	22	16	15	22	15, 16	22
	L	13, 28	5. 10	11	11	11	6, 7
July	H	26	4, 26	27	17, 25	17	24
	L	30	30	29	31	21	14
Aug.	H	16	21	12	15	7	16
	L	27	1, 3, 4, 26, 27	4. 9	3, 23	26	29
Sep.	H	12	19	19	19	12	19
	L	8	15	21	14	7	14
Oct.	H	4, 5, 21	22	4	6	21	22
	L	10	25	27	30	9, 30	30
Nov.	H	6	6	6	6	25	6
	L	29	28	18, 29	27	30	30
Dec.	H	10, 13	13	13	13	9	7
	L	20	20	20	1, 20	28	28

AT KENDAL, 1791.

	Morning.			Noon.			Night.			month, means.
	Mean	high.	low.	Mean	high.	low.	Mean	high.	low.	
Jan.	38.3	48	23	40.4	48	32	38.8	48	30	39 2
Feb.	36.5	46	26	41.9	50	36	36.5	46	28	38.3
March	38.3	47	23	47.2	55	39	40.5	48	25	42
April	43 7	53	36	52.8	67	42	44.1	55	37	46.9
May	45	55	34	56.5	73	44	45.1	61	33	48.9
June	51 1	59	38	63.8	81	48	52.2	62	40	55.7
July	54.3	67	48	63.5	78	51	54	66	48	57.3
August	54.8	66	45	64.3	74	48	53.8	62	46	57.6
Sept.	50.3	60	38	63 4	79	52	51.5	60	42	55.4
Octo.	43	57	24	51.8	60	42	43.9	57	24	46.2
Nov.	39.4	49	22	45.2	53	39	39.3	50	28	41.3
Dec.	29	40	10	33	42	20	30.2	46	-10*	30.7
ann. ms.	43.6			52			44.2			46.6

* Thermometer at 8½ P. M. —6°; at 9 — 10°, and till 10 P. M. — 6°

AT KESWICK, 1791.

	Morning.			Noon.			Night.			month. means.
	Mean	high.	low.	Mean	high.	low.	Mean	high.	low.	
	°	°	°	°	°	°	°	°	°	°
Jan.	37 9	45	24	39 3	49	31	39.2	49	31	38.8
Feb.	35.8	47	25	38.4	47	30	36.7	47	30	37
Mar.	40.4	47	22	43 6	54	34	41.8	48	29	41.9
April	44.4	54	36	49.6	65	41	46 1	59	37	46.7
May	47	64	37	52.7	70	40	48.9	66	40	49.5
June	54 2	70	41	59.3	76	45	56 3	73	41	56.6
July	56.4	70	50	59.8	73	51	57.6	71	50	57.9
August	55.6	64	48	60 9	68	47	58 2	67	45	58.2
Sept.	53.2	66	41	59.1	73	49	56.6	69	46	56 3
Octo.	43.5	55	27	47.7	61	36	46.4	58	32	45.9
Nov.	39 1	47	22	42.3	51	33	40.6	51	32	40.7
Dec.	29.9	39	13	33 2	40	22	32.1	41	15*	31.7
ann. ms.	44 8			48 8			46.7			46.8

1791.

		Morning.		Noon.		Night.	
		Kendal.	Keswick.	Kendal.	Keswick.	Kendal.	Keswick
Jan.	H	31	25	16, 31	16	16, 30	10
	L	28	28	5	28	3	28
Feb.	H	14	14	7	14	10	14
	L	4	4	4, 23	4	16, 28	2, 3
Mar.	H	15	29, 30	28, 30	30	22	29
	L	2	1	3	21	1	1
Apr.	H	17	15	16	16	16	16
	L	1	11	6	5	25	6, 10
May	H	28	31	30	30	30	30
	L	4, 8	6	1	1	6	3, 6, 23
June	H	4	4, 5	6	4	3. 5	3
	L	14	11, 12	21	12	13, 21	12
July	H	18	17	17	16, 17	17	17
	L	5, 14	5, 6	4	4	10	4
Aug.	H	15	23, 24	15	12, 20, 23	14	23
	L	19	30, 31	31	31	31	31
Sep.	H	10	11	11	11	10	11
	L	30	19	22	19	1	18
Oct.	H	4	4	3. 4, 5	3	3	3. 4
	L	24	23	26	22	23	23
Nov.	H	11	11	13	11	11	11
	L	6	6	6, 18, 30	6	6	18
Dec.	H	2, 31	23, 31	2, 31	1, 27, 31	1	1
	L	15	11	11	11	11	11

AT KENDAL, 1792.

	Morning.			Noon.			Night.			month. means.
	Mean	high.	low.	Mean	high.	low.	Mean	high.	low.	
Jan.	32.3	46	11	37.5	48	20	32.5	49	12	34.1
Feb.	37	49	18	44	55	35	37.6	46	27	39.5
March	38.2	48	20	46.3	54	32	39.3	48	22	41.2
April	45	52	36	54.4	72	43	43.9	50	29	47.8
May	45.3	52	35	54.8	62	47	45.4	52	36	48.5
June	52.1	61	48	61.4	75	52	50.2	58	44	54.5
July	56.1	62	51	64.3	72	56	54.9	62	50	58.4
Aug.	55.6	66	48	69	83	58	56.1	66	48	60.2
Sept.	47.6	59	34	56.8	69	46	48.5	59	36	51
Oct.	43.4	58	28	51.4	63	46	44	56	35	46.3
Nov.	41.6	50	24	47.1	58	34	42	51	30	43.6
Dec.	36.9	50	21	40.3	51	29	37.7	52	24	38.3
an. ms.	44.3			52.3			44.3			47

AT KESWICK, 1792.

	Morning.			Noon.			Night.			month. means.
	Mean	high.	low.	Mean	high.	low.	Mean	high.	low.	
Jan.	32 1	45	12	35	47	20	33.4	47	17	33.5
Feb.	36.5	47	19	41.2	53	30	39.7	50	30	39.1
March	37.3	47	17	42.3	51	25	39.6	47	21	39.7
April	44.8	53	35	51.2	67	41	46.9	65	35	47.6
May	46.5	53	36	51.8	62	40	48.2	56	39	48.8
June	53.4	63	46	57.1	66	48	54	63	46	54.8
July	57.3	63	49	61.4	69	50	57.9	65	48	58.9
Aug.	60	71	47	65.2	75	54	59.9	70	48	61.7
Sept.	48.9	59	33	53.9	64	43	51.2	60	42	51.3
Oct.	44.9	57	32	48.8	64	41	46.6	57	37	46.7
Nov.	42.2	55	23	45.7	60	32	44.2	57	33	44
Dec.	36.4	51	20	38.7	51	23	38	49	24	37.7
an. ms.	45.0			49.4			46.6			47

1792.

1792.

		Morning		Noon		Night	
		Kendal.	Keswick.	Kendal.	Keswick.	Kendal.	Keswick.
Jan.	H	31	31	30, 31	31	30	30
	L	13	11	11	11, 12	11	11
Feb.	H	2	2	26	12	6, 27, 29	26
	L	21	21	18, 19, 24	18	20, 21	18, 20, 21
Mar.	H	29	1	17	1, 2	17,24,28	2,17,30
	L	11	9	13	8	9	8
Apr.	H	13, 14, 29	12, 13	10	11	11, 13	11
	L	7	5, 20	5	5	20	19
May	H	19	15	27	12	24, 27	24
	L	11	1	1, 3	1, 2	2	1, 10
June	H	5	16	29	16	16	4
	L	2, 10, 20	8, 10	12	19	2	19
July	H	16	9, 10, 15, 24	29	29	15	31
	L	30	1	5, 11	11	28	11
Aug.	H	1	3	1	3	2	3
	L	28, 29	28	20	28	19, 28	28
Sep.	H	13	2, 7	2	2	7	4
	L	16, 22	22	21	22	15	27
Oct.	H	1	1	1	1	1	1
	L	12	24	12	3, 4	11	24
Nov.	H	3, 5, 8, 11	5	5	5	3	5
	L	17	17	20	17	19	16, 17, 19
Dec.	H	10, 18, 20	18	18	18	18	18
	L	25, 31	24	23	24	7	23

The monthly and annual means of the thermometer, upon 5 years, are as under.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.
At Kendal	36.6	39.5	39.2	45.2	51	55.8	57.1	58.2
At Keswick	36.8	39.5	39	45.3	52.7	57.1	58.8	60.2

	Sept.	Oct.	Nov.	Dec.	annual mean.
At Kendal	52.7	46.3	40.6	35.1	46.4
At Keswick	53.9	47.1	41.3	35.4	47.3

The

The annual mean at *Kefwick* may perhaps be ftated more accurately at 46°, as the evening obfervations were taken too foon to give the true mean temperature. It may however be proper to obferve here, that the time or times of the day at which the obfervations ought to be made, in order to determine the true mean, has not, that I know of, been afcertained.

I made the following obfervations on the temperature of a pump well, the furface of which is ufually from 3 to 6 feet below that of the ground; at the end of January its heat was 45°; February, 45°; March, 46°; April, 46°.5; May, 48°; June, 50°; July, 51°; Auguft, 52°; September, 50°; October, 48°.5; November, 47°.5; December, 45°.————Thefe obfervations give an annual mean of 47°.8.

About the middle of June, 1793, I found the temperature of feveral wells in *Kendal*, after having pumped a few gallons of water from each; fix of the deepeft, being from 5 to 10 yards below the furface of the ground, were juft 48° each; three other deep ones were 47°.5; one not quite fo deep was 46°; and three that were only 2 or 3 yards below the furface of the ground were 49° each. The deep ones, I believe, in general are fubject to very little variation in temperature all the year round.

From thefe obfervations on the temperature of wells, I am inclined to think, the heat of the earth at 10 or more yards depth is not the fame, at *Kendal*, as the mean heat of the air, but fomething greater. Perhaps this is a general fact; the temperature of the cave of the obfervatory at *Paris*, which is 30 yards below the pavement, is 53°.5; whereas the mean heat of the air there, is only 52°.——However this may be, I cannot believe the mean heat of the air at this place is fo great as that of the pump water.

SECTION

SECTION THIRD.

Of the Hygrometer.

THE hygrometer is an inftrument meant to fhew the difpofition of the air for attract-ing water, or for depofiting the water it has in folution with it.

Some of the greateft philofophers of the pre-fent age have been endeavouring to improve thofe inftruments of this defcription we have al-ready, and to invent others lefs objectionable; but I prefume the object is not yet fully attained. —To afcertain the exact quantity of water in a given quantity of air, and alfo the difpofition of the air for imbibing or depofiting it, is an object indeed, highly important to the fcience of mete-orology, and to philofophy in general.

It does not fuit our intended brevity to enter into a detail of the different inftruments lately propofed, with their refpective merits and de-merits; we fhall only obferve, that moft fub-ftances are affected more or lefs with the drynefs and moifture of the air, particularly animal and vegetable fibres, which become turgid, and con-tract by being expofed to moift air. Spunge, paper, &c. imbibe moifture, and become alter-nately

nately lighter and heavier by being expofed to
the air.   Strings, whether made of animal or
vegetable fibres, twift and untwift by the moi-
fture and drynefs of the air, and confequently
are fhortened and lengthened alternately.————
The force with which a cord contracts is amaz-
ingly great.   Mr. *Boyle*, who feems to have
been the firft that made a feries of experiments
of this fort, ufed to fufpend a weight of 50 or
100lbs. to the end of a rope, which was alter-
nately raifed and lowered by the moifture and
drynefs of the air, as a fmall weight would
have been.

Obfervations on the Hygrometer.

THE only hygrometrical inftrument I have ufed, is a
piece of whip-cord, about 6 yards long, faftened to a nail
at one end, and thrown over a fmall pulley ; in this manner
it has been kept ftretched, by a weight of 2 or 3 ounces,
fince September, 1787.   It is in a room without a fire, and
where the air has a moderate circulation ; the fcale is di-
vided into tenths of an inch, and begins at no determined
point ; the greater the number of the fcale, the longer is
the ftring, and the drier the air.   This ftring has varied in
length above 13 inches, or $\frac{1}{16}$ of its whole length.   The
obfervations were taken three times a day the two firft
years, and once a day after, namely, at noon.————The
refult follows.

Mean

Mean ſtate of the Hygrometer, at Kendal.

	1788.	1789.	1790.	1791.	1792.	Mean of the whole.
January	40.3	83.4	85	85	102.6	79.3
February	54.7	81	92.8	97	100.5	85.2
March	81	106	109	105.7	112	102.7
April	85	112	131.7	116	125	113.9
May	116	123	129	123	128	123.8
June	127	127	129	135	137	131
July	104	126	126	131	134	124.2
Auguſt	113	132	121	129.6	138.5	126.6
September	108.5	114	117	129	120.7	117.2
October	102	104	109	119	123.3	111.5
November	87.6	99	104	113	106.4	102
December	100	85	92	107.7	102.6	97.5
An. means	93.3	107.7	112.1	115.9	119.2	
Drieſt	138	140	141	144	150	
Moiſteſt	15	63	71	65	83	

It is obvious, from the means of the ſeveral years, and likewiſe from the extremes, that the cord has been increaſing in length each year, ſo that, in ſimilar ſtates of the air, the index pointed at greater numbers each year ſucceſſively; this increaſe too appears to have been nearly in arithmetical progreſſion after the firſt year.——In conſequence of this increaſe in the length of the cord, ſome allowance ought to be made in comparing the mean ſtate of the hygrometer in the different months of the year; thus, if the months of June or July be taken for a ſtandard of compariſon, then the means of the preceding months muſt be increaſed, and thoſe of the following diminiſhed, in ſuch proportion as the annual increaſe ſhall require.

The above mentioned inſtrument ſerves to ſhew a variation in the dryneſs or moiſture of the air; but it is very inadequate to the purpoſe for which a hygrometer is deſired.

F

SECTION

SECTION FOURTH.

Of Rain-gauges, and an account of the quantity of rain that fell at Kendal *and* Keſwick, *in the years* 1788, 1789, 1790, 1791, *and* 1792, *together with the quantity at* London *in the three firſt of theſe years.*

THE *rain-gauge* is a veſſel placed to receive the falling rain, with a view to aſcertain the exact quantity that falls upon a given horizontal ſurface at the place. A ſtrong funnel, made of ſheet iron, tinned and painted, with a perpendicular rim two or three inches high, fixed horizontally in a convenient frame with a bottle under it to receive the rain, is all the inſtrument required.

In order to determine the depth of water that falls in the open field, with this apparatus, we muſt have given, 1ſt, the weight of the water caught in the bottle; 2d, the area of the aperture of the funnel; and, 3d, the weight of a cubic foot of water, which has been found equal to 62½lbs. avoirdupoiſe. Then, if a = the area of the aperture, in inches, W = 62½lbs. and w = the weight of the water caught, in pounds, we ſhall have this theorem, per menſuration,

20736

= the depth of water, in inches, that

n any horizontal furface at the time and

required.

verting this theorem, one may eafily

weight of water correfponding to any

pth; which being once found, it is

ieditious, and fufficiently accurate, when

el has 8 or 10 inches diameter, not to

ie water each day, but to *meafure* it,

s of phials, &c. fuitable for the purpofe.

following account, we have given the amount of

.ch month, at *Kendal* and *Kefwick*, for 5 years,

3 months at the laſt place; and alfo at *London*,

: the laſt is taken from the Philofophical Tran-

The rain at the two before mentioned places was

evening at 8 or 10 o'clock.——To the account

dded, the number of *wet days* each month, or

which the rain amounted at leaſt to .001 of

My rain-gauge at *Kendal* is 10 inches diameter;

roſthwaite's at *Kefwick* about 8 : they were both

diſtant from trees, houfes, &c.

1788.

	At Kendal.		At Keswick.		At London.
	Inches of rain.	wet days	Inches of rain.	wet days	Inches of rain.
Jan.	5.6160	20			0.439
Feb.	3.3064	23			1.461
March	2.8183	16			0.336
April	2.9047	16	3.9204	22	0.607
May	1.1872	10	2.0840	9	0.497
June	2.3137	7	3.6876	9	3.275
July	7.0323	28	6.3757	28	1.620
Aug.	3.0883	18	5.0771	19	2.699
Sept.	4.6756	19	7.1382	23	3.345
Oct.	2.1220	11	1.7537	13	0.103
Nov.	3.0460	18	3.2841	17	0.510
Dec.	1.1470	7	0.9849	12	———
Total	39.2575	193	34.3057	152	14.892
from Mar.	27.5168	124			

1789.

	At Kendal.		At Keswick.		At London.
	Inches of rain.	wet days	Inches of rain.	wet days	Inches of rain.
Jan.	7.343	22	8.5435	26	1.345
Feb.	8.924	24	9.0442	27	1.605
March	1.347	15	1.3245	21	1.549
April	4.778	19	4.2383	21	0.957
May	5.388	20	3.6611	25	1.103
June	4.311	18	7.0637	19	3.244
July	6.389	25	5.2770	26	2.467
Aug.	1.556	12	3.4569	14	1.864
Sept.	5.436	24	7.2709	24	2.155
Oct.	6.864	21	8.0907	25	3.253
Nov.	5.451	16	6.0965	21	1.244
Dec.	12.048	28	8.1776	27	1.190
Total	69.835	244	72.2449	276	21.976

1790.

	At Kendal.		At Keswick.		At London.
	Inches of rain.	wet days	Inches of rain.	wet days	Inches of rain.
Jan.	6 567	18	5.9377	19	0.967
Feb.	3 662	15	4.0124	17	0 115
March	1.606	10	1.3228	10	0.122
April	1.960	11	2.3198	17	1.470
May	2.645	14	3.4588	18	2.898
June	4.114	17	5 1077	21	0.708
July	7.894	25	6.2509	24	1.700
Aug.	6.200	26	5.8524	26	1.991
Sep.	6.682	16	8.3950	20	0.368
Oct.	5.382	15	6.1304	16	1.108
Nov.	5.345	12	5.0550	13	2.512
Dec.	10 306	24	10.9010	24	2.093
Total	62.363	203	64.7439	225	16.052

1791.

	At Kendal.		At Keswick.	
	Inches of rain.	wet days.	Inches of rain.	wet days.
Jan.	8.369	28	11.3574	28
Feb.	6.641	16	9.2244	21
March	3.641	17	3.1231	17
April	4.810	17	3.3190	21
May	3.983	18	3.9963	18
June	3.493	13	2.0133	20
July	6.344	18	8.2060	20
Aug.	5.165	17	5.8852	16
Sep.	3.409	10	2.7715	11
Oct.	5.505	22	7 1272	23
Nov.	6.465	21	8.7238	23
Dec.	8.375	22	7.8050	23
Total	66.200	219	73.5522	241

1792.

	At Kendal.		At Keswick.	
	Inches of rain.	wet days.	Inches of rain.	wet days
Jan.	4.120	13	4.5041	15
Feb.	5.820	14	4.9375	20
March	6.684	23	9.6261	26
April	10.091	16	11.6460	17
May	5.922	19	6.5167	21
June	3.514	16	2.7110	20
July	5.926	21	3.8643	20
Aug.	7.398	18	5.9704	16
Sep.	11.229	28	10.6179	25
Oct.	6.028	20	6.7357	21
Nov.	6.030	18	5.8350	14
Dec.	12.122	27	11.6404	23
Total	84.884	233	84.6051	238

Mean

Mean monthly rain and number of wet days, at Kendal *and* Keſwick, *for all the 5 years,*

	At Kendal.		At Keſwick.	
	Inches of rain.	wet days.	Inches of rain.	wet days.
Jan.	6.403	20	7.3558	22
Feb.	5.671	18	6.1624	22
March	3.219	16	3.7324	18
April	4.909	16	5.0887	20
May	3.825	16	3.9434	18
June	3.549	14	4.1167	18
July	6.717	23	5.9948	24
Auguſt	4.681	18	5.2484	18
Sept.	6.286	19	7.2387	21
Octo.	5.179	18	5.9675	20
Nov.	5.267	17	5.7989	18
Dec.	8.800	22	7.9018	22
Total	64.506	217	68.5495	241

The greateſt quantity of rain in 24 hours, for theſe 5 years, was on the 22d of April, 1792, namely, at *Kendal,* 4.592 inches. The rain at *Keſwick* on that day, was ſomething leſs ; but taking both the 22d and 23d, the rain was nearly equal at both places.

Beſides theſe 2, there were other 2 days, at *Kendal,* when the rain was betwixt 2 and 3 inches, and 56 days betwixt 1 and 2 inches.

At *Keſwick,* for 4 years and 9 months, there were 3 days, beſides the 2 above mentioned, when the rain was between 2 and 3 inches, and 52 days between 1 and 2 inches.

SECTION

SECTION FIFTH.

Obfervations on the Height of the Clouds.

MR. *Crofthwaite*, of *Kefwick*, has availed
himself of his fituation in the vicinity of
high mountains, to make obfervations on the
height of the clouds; for which purpofe he has
chofen *Skiddaw*, the higheft mountain in the
neighbourhood, a very fine view of which his
mufeum commands. By means of marks on the
fide of the mountain, and with the affiftance of
a telefcope, he can difcern, to a few yards, the
height of the clouds, when they are below the
fummit, which is very often the cafe.—Perhaps
the following feries of obfervations is the only
one of the kind extant, as the labour and diffi-
culty attending fuch obfervations in a champaign,
or flat country, are fufficient to deter any one
from making two or three daily obfervations for
a feries of years; and when the whole fky is
clouded, they are quite impracticable.

He has determined, by trigonometry, the per-
pendicular height of *Skiddaw*, above the level of
Derwent lake, to be 1050 yards, which agrees
very nearly with Mr. *Donald's* obfervations; and
he has noted, in a column of his meteorological
journal,

journal, every morning, noon, and evening, the height of the clouds, in yards, above the level of the faid lake, when their height did not exceed that of *Skiddaw*, and when it did, he has marked it as fuch.

The refult of 5 years obfervations is contained in the following table. All the obfervations when the clouds were between 0 and 100 yards high are placed in one column, and thofe when they were between 100 and 200 yards high in the next column, &c.—In order to determine what effect the feafons of the year have upon the clouds, in this refpect, we have kept the obfervations in the feveral months diftinct.—It is to be noted, that the column containing the number of obfervations when the clouds were above *Skiddaw*, includes thofe obfervations when there were no clouds vifible; but Mr. *Crofthwaite* has noted this laft circumftance alfo, in the journal, and it appears, that about 1 obfervation in 30, of thofe in that column, fhould be deducted on that account.

Clouds

	Clouds from 0 to 100 yards high.	From 100 to 200 yards high.	From 200 to 300 yards high.	From 300 to 400 yards high.	From 400 to 500 yards high.	From 500 to 600 yards high.	From 600 to 700 yards high.	From 700 to 800 yards high.	From 800 to 900 yards high.	From 900 to 1000 yards high.	From 1000 to 1050 yards high.	Above 1050 yards high.	Number of observations.
Jan.	0	9	12	28	53	39	37	32	30	39	36	116	431
Feb.	5	10	5	15	41	45	45	27	43	38	29	94	397
Mar.	2	1	6	11	22	40	32	36	24	32	44	184	434
Apr.	0	4	5	18	24	34	37	26	23	38	35	206	450
May	0	1	4	8	13	31	22	25	30	34	27	270	465
June	0	2	2	6	24	24	29	21	34	41	34	233	450
July	0	2	2	18	35	36	35	25	35	48	38	191	465
Aug.	0	4	5	13	27	39	35	26	25	45	30	215	464
Sep.	0	1	7	13	38	38	32	30	27	51	27	186	450
Oct.	2	0	5	13	26	49	31	31	46	61	37	164	465
Nov.	0	0	3	13	30	58	42	38	46	45	47	128	450
Dec.	1	8	6	23	41	53	39	50	47	46	35	111	460
Total	10	42	62	179	374	486	416	367	410	518	419	2098	5381

It may be proper to observe, that the supposition of the clouds rising or falling with the barometer, or as the density of the air increases or diminishes, is not at all countenanced by these observations.—Also, that in very heavy and continued rains, the clouds are mostly below the summit of the mountain; but it frequently rains when they are entirely above it.

G

SECTION

SECTION SIXTH

Account of Thunder-ftorms and Hail-fhowers.

WE fhall arrange the dates and accounts of thefe, in the order of their fucceffion. When the diftance of the thunder is mentioned, it is calculated by obferving the number of feconds between feeing the lightning and hearing the thunder, and allowing 1142 feet of diftance for every fecond of time.

Thunder-ftorms at Kendal *and* Kefwick.

1788.

May 26. Several loud peals of thunder a little befoie 7, and again before 9 P M. the laft very near, at Kendal. The fame at Kefwick, at 7 P M. with a few drops of rain. —The hour from the SE

July 3 From 6 to 7 P M much thunder, and very heavy fhowers at both places It came from the S

Auguft 15 From 7 to 8 P. M thunder and heavy rain, from the NW. at Kefwick.

Auguft 16 At $7\frac{1}{2}$ P M. a tremendous ftorm paffed on the SE. of Kendal, 8 or 10 miles diftant, 20 or 30 flafhes and reports fucceeded each other in about half an hour.

September 26 Diftant thunder in the night, at Kendal. At $7\frac{1}{2}$ P. M. 2 claps at Kefwick, with much rain,

1789.

April 27. At 3½ P M ſome loud peals of thunder, at Kendal

Miv 13 From 6' to 7 P M. ſeveral loud claps of thunder diſtant, at Kendal —Between 7 and 8 P M much thunder heard at Keſwick, from the SW

Miv 17 A little before 3 P M one clap of thunder heard at Kendal

June 12. Diſtant thunder in the evening at Kendal.

——— 19 Diſtant thunder P M at Kendal

——— 20 At 1 P M ſeveral claps at Kendal,—the ſtorm returned at 4 P. M and there were 35 peals in ¾ of an hour, many of them uncommonly loud, and near, there was rain in the mean time, but not heavy

N B A woman was killed by lightning, in a houſe at *Sedbergh*, about 11 miles from Kendal

June 27. Diſtant thunder in the evening, at Kendal

July 4 Diſtant thunder at 2 P M at Kendal —Loud thunder, and heavy ſhowers, P M at Keſwick

July 6 After 2 P. M. diſtant thunder, at Kendal

———10. At 3 P. M. a diſtant thunder clap, at Kendal

———19 At 2½ P. M diſtant thunder, at Kendal.

———21. Paſt 5 P M 3 loud peals, at Kendal, and diſtant thunder, at Keſwick.

Auguſt 29 P. M. ſome thunder, with heavy rain, at Keſwick

September 29 After 9 P M much diſtant thunder, with ſhowers, NW at Kendal —At 8½ P M one long and loud peal, at Keſwick.

September 30. Diſtant thunder in the night, at Kendal.

1790.

April 26 At 1 P M ſome peals of thunder, at Kendal.

May 16. At 9 P. M. one loud crack, from the E at Keſwick.

1790.

May 17 At 11½ A. M one loud crack, and a heavy
fhower, at Kefwick

June 9 From 6 to 10 P. M, much thunder, with little
rain, at Kendal.

June 16. Diftant thunder in the evening, at Kendal*.—
At 8½ P. M. feveral loud claps, at Kefwick.

June 22 From 6 to paft 8 A M. much loud thunder,
with rain, at both places

Auguft 27 Some thunder P M at Kendal.

September 3 P M a little thunder, at Kefwick.

1791.

January 5. Loud thunder in the night, with hail, at
Kefwick.

May 21. At 6 P. M. diftant thunder, and hail fhowers,
at Kendal

June 4 Betwixt 1 and 2 P. M. feveral peals of thunder,
at Kendal   The laft of them was the moft remarkable one
ever remembered at this place,—inftantaneoufly after the
flafh, was heard a very loud and tremendous crack, exactly
fimilar, but incomparably more loud, than the report of a
mufket, every houfe in the town was fenfibly fhaken by it,
and univerfal terror produced by the loudnefs and fingularity
of the report, but providentially no harm was done — The
rain, mixed with hail, exceeded in quantity what has ever
been produced here on a fimilar occafion, for 6 years at leaft,
there fell upwards of *one inch and a half* in the fpace of *three
quarters of an hour*, though a confiderable part of that inter-
val was moderate rain

N B It is remarkable that the barometer was ftationary
all that day, and fo high as 30 06.

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* There was, this evening, about Prefton-hall, 6 miles from Kendal,
one of the moft extraordinary torrents of hail and rain, attended with
thunder, that is upon record.

1791.

June 12 At 4 P. M. a crack of thunder, with hail and rain, at Kendal

July 17 At 10 P. M loud claps to the NW. at Kefwick.

———18 After 2 P M. feveral claps, at Kendal; one of which not unlike that of the 4th of June. At Kefwick, 2 claps A. M and 3 P M with exceffively heavy fhowers.

Auguft 15. Between 8 and 9 P M. there was the moft lightning I ever remember to have feen at one time, at Kendal, fome thunder was heard, but it was diftant, E.

Auguft 16 From 5½ to paft 7 A. M. much thunder at both places, and heavy rain at Kefwick.

October 20. At 8½ A M one loud clap of thunder, at Kefwick, and much lightning from 7 to 10 P. M.—heavy rain all day

December 25. Much thunder from 5 to 7 P. M. at Kefwick.

1792.

April 13. At 3 P. M. much diftant thunder, at Kendal.

May 27. Between 3 and 4 P. M fome thunder and rain, at Kendal.

July 9 At 7 P. M. diftant thunder, at Kendal.

———16 P. M much thunder, at Kendal. Between 6 and 8 P M loud thunder, at Kefwick.

July 18. At 8 A M. thunder, at Kendal.

———25 After 6 P M thunder, at Kendal.

Auguft 26 At 3 P M. fome thunder at Kendal.

October 14 In the evening, lightning, and at 10, diftant thunder, at Kendal. From 6 to 11 the fame evening, light-ning, at Kefwick, and at the later hour, one long and loud crack of thunder,

Days on which HAIL *has been noted in the journals at* Kendal *and* Keſwick.

Hail at Kendal	Hail at Keſwick
1788 January 18.	1788. April 4 Nov. 4 Dec 26 & 31
1789 Jan. 18. Mar 9 April 26 Oct 1 Nov. 14 Dec 15 & 16	1789. Jan 15. Feb. 11 April 1, 11, & 24 June 27 Sep 14 & 30. Oct 1 & 30 Nov 13. Dec 15, 16, & 31
1790 Jan. 27. April 25 Aug 3 Dec 11 & 15.	1790 Feb 16 April 11 & 14 July 31 Sep 2 & 3 Dec. 11 & 13
1791. Jan. 5, 7, 11 & 13 Feb. 1 & 11 Mar 21 May 21, 22 & 23 June 4 & 12	1791 Jan 2, 4 & 5 Feb 11, 15 & 18 Mar 21 May 18, 20, 22, 23, & 25 June 12 & 21 July 5 Oct 8 & 24 Nov 5, 16 & 28
1792. Mar. 19 May 22 Oct 17 Dec. 6 & 22	1792. Mar 7 May 1 & 2 June 30 Sep. 20 & 21 Oct. 18 Nov 15.

N B The winds that bring hail-ſhowers are always SW, W, or NW, in theſe places, and the barometer is generally low.

In order to diſcover what particular months or ſeaſon of the year, is moſt liable to thunder-ſtorms and hail-ſhowers, we have collected the ſeveral obſervations, at both places, in each month of the year, into one ſum, and placed them below.

	Jan	Feb	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov	Dec.
Thunder	1	0	0	3	7	5	12	7	4	2	0	1
Hail	11	7	5	8	11	6	2	1	6	7	7	13

SECTION SEVENTH.

Obfervations on the Winds.

I Have before obferved, that my obfervations on the winds refer them all to 8 equidiftant points of the compafs, and to 5 degrees of ftrength, marked o, 1, 2, 3, and 4, refpectively. Mr. *Crofthwaite* has referred them to 32, or the whole number of points, and to 12 degrees of ftrength; but I have reduced his obfervations to agree with my own, in order to prepare the following table of comparifon.

The obfervations at both places were made three times each day, namely, morning, noon, and evening.

It may be obferved, that the high winds do not in general differ materially, either in ftrength or direction, at *Kendal* and *Kefwick*, as might be expected from the proximity of the places; but when the wind is moderate, there is often a difference in direction; probably the mountainous fituations of the places may have fome influence in this laft cafe.

Here follows Tables containing the number of obfervations on the winds each year, in all the different directions, at both places.

WINDS

WINDS AT KENDAL.

Years	N	NE	E	SE	S	SW	W.	NW	Numb of Obſerve
1788	131	139	40	79	91	186	84	87	837
1789	94	118	38	49	94	309	76	46	824
1790	100	195	17	21	25	329	137	47	871
1791	62	259	16	33	19	440	138	50	1017
1792	51	294	33	24	35	472	92	33	1034
Total	438	1005	144	206	264	1736	527	263	4583

WINDS AT KESWICK.

Years	N	NE	E.	SE	S	SW	W	NW	Numb of Obſerve
1788	46	50	158	98	137	105	238	113	945
1789	53	47	150	120	180	146	211	119	1026
1790	32	62	143	105	134	174	237	89	976
1791	44	73	133	66	117	225	257	67	982
1792	49	84	139	88	164	213	219	40	1005
Total	224	316	723	477	732	863	1162	437	4934

To theſe tables we ſhall ſubjoin an account of thoſe days on which the higheſt winds prevailed, at one or both places

Higheſt winds, marked 4, *at* Kendal *and* Keſwick.

1788.

Jan. 19   March 16   April 1 and 3.   Dec. 26 and 27.

1789.

Jan. 13. Feb. 2, 3, 4, 11, 15, and 24   Oct. 1. Nov 18. Dec. 15, 18, 19, 20, 24, 25, and 30

1790.

Jan 11. Feb. 12 and 26   March 10.   June 19.   July 5, 20, and 21. Oct 12. Dec, 15 and 23

1791.

1791.

Jan 4, 5, 7, 8, 11, 12, 13, 15, 17, 18, 19, 24, 25, 29, and 30 —N. B Thefe winds were all W or SW except on the 18th and 19th, SE. Feb 1, 10, 11, 12, 15, 18, 19, and 22 March 4. 13, 19, 21, and 23 May 17 and 19. June 16 Oct. 20 Nov 9, 11, 12, 19, 26, and 27 Dec 1, 13, and 25

1792.

Feb 2 March 18 April 2, 15, 22, and 23. Sept. 10. Oct 1, 2, 3, and 31. Nov 18, 19, 20, and 21. Dec. 4, 5, 6, 9, 10, 11, 18, 20, 22, and 23,

In order to determine what months of the year are moft liable to high winds, we have found the amount of the number of days in the feveral months, on which the higheft winds were obferved, according to the above account.

Jan	Feb	Mar	Apr.	May	June	July	Aug	Sep.	Oct	Nov	Dec
18	17	8	6	2	2	3	0	1	7	12	24.

SECTION EIGHTH.

Account of the firft and laft appearance of Snow, each winter; the Froft, Snow, feverity of the Cold, &c.

MOST people know that fnow firft appears in general upon the mountains; and the higher thefe are, all other circumftances being the fame, the fooner their fummits are covered

H with

with snow, if they exceed a certain height (which varies with the latitude) snow continues upon them all the year round, or is perpetual; but this is not the case with any mountains in *England*.

The highest mountains seen from *Kendal* are to the NW and do not exceed 6 or 7 hundred yards in height, as has been observed, it is these of course that are soonest topped with snow. The mountains in the neighbourhood of *Keswick* are much higher.

The first appearance of *hoar frost*, each autumn, has been pretty carefully noted, but the last appearance of it, in the spring, has not, it being inconvenient at that season to make observations previous to the rising of the sun

The dates of the different appearances follow for each year, together with the mean times; or, those times before or after which, upon an equality of chance, the events may be expected in future.

	Last snow seen on the mountains, in the spring.		The mountains first covered with snow		Hoar and hoar frost on the grass	
	Kendal.	Keswick	Kendal.	Keswick	Kendal.	Keswick
1788	May 30	June 6	Nov 15	Nov 13	Sep 15	Sep 15
1789	May 14	June 30	Oct. 13	Oct 29	Sep. 17	Sep. 17
1790	April 25	April 27	Nov 22	Oct 31	Sep. 8	Sep 4
1791	June 12	June 12	Oct. 22	Oct 22	Oct. 13	Oct 13
1792	May 1	May 13	Nov. 15	Oct. 9	Sep 16	Sep. 15
Mean	May 16	May 17	Nov. 8	Oct. 27	Sep. 20	Sep. 19

1788.

IN the beginning of this year there was very little frost
or snow, the moft snow was on the 7th of March, being
above 2 inches deep, both at *Kendal* and *Kefwick*.

In the beginning of December the froft fet in, and con-
tinued for 5 weeks, the mean ftate of the thermometer for
which time was 28°, and at the end of it the froft had pe-
netrated 16 or 18 inches into the ground.—Above 3 inches
of fnow fell on the 31ft.

1789.

Not much fevere froft after the middle of January —
Snow on the 14th and 21ft of the fame   Much fnow from
the 9th to the 14th of March, about 6 inches deep, at an
average, both at *Kendal* and *Kefwick*

Froft in November, very little in December.

1790.

Little either froft or fnow, in the beginning of the year.

On the 17th, 18th, and 19th of December, much fnow,
4 inches deep, at an average, at both places.

1791.

But little froft or fnow in the beginning of the year

On the 8th, 9th, and 10th of December, a very great
quantity of fnow, the average depth, at *Kendal*, was 11
inches, which was the greateft obferved there for 24 years
paft, the average depth at *Kefwick* was about 8 inches

It was on the evening of the fucceeding day, the 11th,
that the extreme of cold took place, the air was clear, and
the wind from the N. but very moderate, the barometer
was 29.75; it was rifing before this event, and it fell
afterwards.   At *Kendal*, the thermometer at 8½ P. M. was
— 6°, upon the fnow; afterwards it fell to — 10°, in the

morning of that day it was 15°, and 20° at noon.—During the extreme cold, a prodigiouſly denſe miſt was carried from the river into the town, in which the thermometer fell no lower than 3°, whilſt it was — 10° to the N. of the river, and the air quite clear. The next morning the thermometer was at 18°, and the day windy, with ſhowers of ſnow, hail, and rain.

Probably the cold at *Keſwick* was as extreme as at *Kendal.* Mr *Croſthwaite*'s loweſt obſervation was 6° ; but the proximity of his thermometer to the houſe, might be a means of keeping up the temperature in ſuch an extremity as this.

1792.

Strong froſt the ſecond week in January
Little froſt or ſnow in November and December.
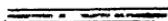
SECTION TENTH.

Account of Bottom winds *on Derwent lake.*

DERWENT lake is one of thoſe few which are agitated at certain times, during a calm ſeaſon, by ſome unknown cauſe. The phenomenon is called a *bottom wind.*

Mr.

Mr. *Crofthwaite* has been pretty affiduous in procuring intelligence refpecting thefe phenomena, and in obferving any circumftance that might lead to a difcovery of their caufe; but nothing has occurred yet that promifes to throw light on the fubject.

N. B. The *lake* is near *Kefwick*.

The following is an account of the times and circumftances of the feveral obfervations.

1789.

April 30 From 8 A. M. till noon, the lake pretty much agitated

Auguft 9. At 8 A. M. the lake in very great agitation; white breakers upon large waves, &c. without wind.

Auguft 27. At 9 A M. a fmall bottom wind.

1790.

June 20 At 8 P. M a bottom wind on the lake.

October 11. At 8 P. M a bottom wind on the lake.

December 1. At 9 A. M a ftrong bottom wind on the lake.

1791.

The phenomena that took place this year, if any, were not noticed.

1792.

October 28. At 1 P. M. a bottom wind; the water much agitated,

SECTION

SECTION ELEVENTH.

Account of the Auroræ Boreales *seen at* Kendal *and* Kefwick.

THE *aurora borealis*, or that phenomenon which in *England* is called the *Northern lights*, or *ftreamers*, has appeared frequently to all the northern parts of *Europe* fince the year 1716, though it feems to have been a rare phenomenon before that time.

Sometimes the appearance is that of a large, ftill, luminous arch, or zone, refting upon the northern horizon, with a fog at the bottom; at other times, flafhes, or corufcations, are feen over a great part of the hemifphere.—We fhall defcribe the general phenomena more at large in the effay on the fubject, in the fecond part of this book; and particular obfervations will be given at large in the addenda to this lection.

Explanation of the following Lift.

IN the firft column we have given the month and day on which the *aurora* was feen, in the fecond, the hour P M., when no hour is mentioned, it is to be underftood to have happened between the end of the twilight and 10 o'clock. The third column contains the moon's age at the time, or the number of complete days betwixt the *change*
and

and the *aurora*, the fourth contains the days in like manner betwixt the *full* and the *aurora*, the reasons for thefe two columns will appear in the Effay. In the fifth column we have characterized the *aurora*, by one or more words. *ftill*, denotes the northern horizontal arch, and *active*, denotes thofe appearances when diftinct flafhes and coinfcation. were feen. but this diftinction was not always attended to, and if it had, the *aurora* often exhibits both appearances at the fame time. *grand*, denotes a large difplay of ftreamers over great part of the hemifphere, *high*, denotes near the zenith, and *low*, near the horizon, apparently

N B. The dates of thofe obfervations not characterized, I received from a friend, they may be depended on as authentic.

A Lift of the Aurorae Boreales *obferved at* Kendal *and* Kefwick, *for 7 years, namely from May* 1786 *to May* 1793, *together with the moon's age at the refpective times of obfervation.*

N. B. For diftinction's fake we have marked all thofe that were obferved at both places with z, and thofe obferved at *Kefwick* only, with 1, the reft were obferved at *Kendal* only. —Thofe marked D, were doubtful obfervations, from twilight, or other caufes.

1786.	Hour P M.	D's age, at laft full	Character.	1786	Hour P M.	D's age, paft full	Character.
May 1	3			Sep. 21	29	14	
——11	13			——26	4		
——22	24	9		——29	7		
July 15	20	4		Oct 13	21	6	
Aug 11	17	2		——25	3		
——17	23	8		Nov. 14	23	8	
Sep 8	16	1		Dec 25	5		active, low.
——19	27	12					
——20	28	13				Number 16	

1787	Hour P M	D's age.	D past full	Character	1788	Hour P M	D's age	D past full	Character
Jan. 12		23	9		Jan 13	8	5		transient
—24		5			—14	8	6		large, still
—25		6			—15	9	7		large, still
Feb. 22		4			Feb 1	9	27	12	still
Mar 21	8	2		active, high	—6		20	1	active, high 1
—24	8	5		active, high	—7		0		small 1
Apr. 19	9	1		high D	—8		1		faint, still
—20		2		high D	—12		5		active small 1
—26		8		active, low	Mar 7	11	0		active, small 2
May 12		24	10	faint D	—8		1		active, small
—16	9	28	14	high. D	—28	10	21	6	bright, large
—17	9	0		active	Apr 1	10	25	10	
—18	11	1		active	—3	10	27	12	large, grand
June 7	11	21	7	active	—7	10	1		a glance, clouds
Aug 7	9	24	9	active	—14	12	8		
—19	10	6		active	—27	10	21	7	still, low
Sep 19	9	8		bright, still	—28	10	22	8	active, high 2
Oct 4	10	22	7	still	—29	10	23	9	large, active
—6	10	24	9	active, faint	—30	10	24	10	still
—7	10	25	10	active, large	May 1	10	25	11	a glance, cloud
—17	11	6		active (a)	—4	10	28	14	transient
—19	9	8		still	—10	10	4		high D
Nov 4	9	24	9	large, bright	—11	10	5		large, still
—8	8	28	13	large, bright (b)	—24	10	18	4	very grand (c) 2
—28	9	19	3	still, small	—25	11	19	5	grand
—29	9	20	4	still, small	—27	10	21	7	active
—30	9	21	5	still, small	June 3		29	14	large D
				Number 27	July 30		27	12	active
1788					Aug 1	10	0		active (d)
Jan 9	6	1		still, low	—2	10	1		active
—10	8	2		still, large 2	—3	10	2		small
—11	8	3		still, faint	—19	10	18	3	large, still 2

1788

(a) A heavy shower, with thunder, just before.

(b) Several flashes of lightning with it, after a very wet day.

(c) From 10 to 11 P M uncommonly brilliant, active streamers over most of the hemisphere they were said to be heard.—Not much interior the next night.

(d) Splendid streamers, extent from NL. to W., no fog beneath.

1788	Hour P M	☽'s age	☽ past full	Character.	1789	Hour P M	☽'s age	☽ past full	Character
Aug 23	22	7		very grand(a) 2	—29		3		a glance, clouds
—29	10	28,13		active	—30		4		a glance, clouds
Sep 2	2			full	Apr 12	17	2		full
—6	6			a glance, clouds	—13	18	3		full 2
—10	10			faint, full	—30		5		full
Oct 12	4	12		full	June 12	10	19	5	active
—21	10	22	6	full	Aug 13	22	8		active, high 1
—24	25	9		full	—14	10	23	9	active, high
—27	28	12		full 1	—15	9	24	10	full
—30	9	1		full	—16	10	25	11	full
—31	9	2		large, full	—17	10	26	12	full
Nov 1		3		full	—18	10	27	13	active
—19	9	21	6	full	—19	10	28	14	active, high
—27		0		faint, full	—20	10	0		active
—28		1		bright, full	—25		5		active 1
—30	7	3		full	Sep 11	10	24	10	full (d)
Dec 21	2	8		full 2	—15	10	25	11	full
—24	27	11		active	—20	10	1		fine, active 2
				Number 53	—23		4		fine, clouds
					—26		7		grand(e) 2
1789					Oct 18		0		active
Jan 11	15	0		full	—19	11	1		active
Feb 15	20	5		active, small 1	—20		2		grand(f)
—23	11	28	13	active	—23		5		large, full 2
—26	10	1		large, active	—25		7		full
—28		3		large, bright(b)	—27		9		full
Mar 14	17	3		very grand(c) 2	—31	8,13			full
—16	19	5		full, small					

I

(a) Soon after 8 P. M. a broad arch was observed, extending quite across the heavens, through the zenith, from E. to W. nearly, but its eastern extremity inclined to the north, and its western to the south afterwards an uncommonly grand display of streamers over two thirds of the hemisphere

(b) At 9½ P. M. there was a large bow, like that of the 23d of August last.

(c) It began in S. of the prime vertical, and afterwards spread northward.

(d) Flashes of lightning, both this evening and the preceeding.

(e) Most of the hemisphere finely illuminated with streamers

(f) From 8 to 10 a grand display of streamers over great part of the hemisphere.

1789.	Hour P.M.	D's age.	D past full.	Character.	1790.	Hour P.M.	D's age.	D past full.	Character.
Nov. 4		17	1	still	Oct. 31	8½	23	8	still
—10	11	23	7	still	Nov. 7	10	1		still
—14		27	11	bright (a) 2	—8	9	2		still
—19		2		large, still 2	—9	9	3		still
—21		4		active 2	—10	10	4		still
—22		5		fine, active	—12	10	6		still
—24	11	7		still	—16	10	10		still
—25	10	8		still	—27	8	21	6	fine, active 2
—26		9		still	—28	8	22	7	still, faint
—27	10	10		active	—30	10	24	9	still, faint
Dec.14		27	12	still, clouds	Dec 25		19	4	still, faint
				Number 45.	—28		22	7	still, faint
1790.									Number 36.
Jan. 14	7	29	13	still	1791				
Feb. 3		19	4	still	Jan. 6	9	2		very grand 2
—9		25	10	still	Feb. 25		22	7	bright, still
Mar. 10		24	9	still, faint	Mar. 3		28	13	still
—16		1		still	—5		1		still
—17		2		still, faint	—7		3		still 2
—18		3		still	—26		22	6	large, still
—19		4		still, bright	—29		25	9	still, low
—20		5		still, bright	Apr. 3		0		still, small
Apr. 3		19	4	still, low	—20		17	2	still
—4		20	5	active, low	—23		20	5	still
—5		21	6	still, faint	—25		22	7	still, small
—6		22	7	still	May 12	10		9	active
—7	11	23	8	still	—20	11	17	2	active
—9		25	10	still	June 10		9		active
—16	11	2		active	Sep 5		7		active
—17	10			large, still	—8	10	10		still, small
May 12		28	13	active	—11	9	13		still
—14		0		still	—13		15	1	still
—16		2		still	—27		0		still
—18		4		still	—28		1		still
Sep. 7	9½	28	14	still	Oct. 15		18	3	still
Oct. 9		1		still, faint	—19		22	7	still
—18	7½	10		still 1	—20		23	8	active (b)

1791.

(a) Lightning afterwards.　　　(b) Thunder at a distance this evening.

1791	Hour P.M.	D's age.	D past full.	Character.
Oct 22		25	10	still, bright 2
—23		26	11	still
—29		2		large, bright
—31		4		active
Nov 3		7		large, active 2
—4		8		still, faint
—5		9		still, faint
—11		15	1	still
—14		18	4	still
—17		21	7	still
—18		22	8	still
Dec. 13	6½	18	3	fine, active
—19		24	9	still
—26		1		still
				Number 37.
1792.				
Jan. 9	10	15	0	large, still
—17		23	8	still, faint
—18		24	9	still, faint
Feb. 9		17	1	still
—17		25	9	still
Mar. 2		9		still
—15		22	7	large, bright
Apr 10		19	3	very grand 2
—11		20	4	grand 2
—16		25	9	still, bright
May 6		15	0	active

1792	Hour P.M.	D's age.	D past full.	Character.
June 30	1	10		active
Aug. 4	1	16		2 active, small
—23	10	6		active
Sep. 22	10	6		bright. still
Oct. 12	10	26		12 small, still
—* 13		27		13 very grand 2
—14		28		14 active 2
—18	10	3		small
—23		8		still
—31	8½	16		2 active, low
Nov. 19	9	4		still 2
Dec. 7		23		still 1
				Number 23.
1793.				
Jan. 11	10	29	14	still, small
—12		0		active
—13		1		still
Feb. 8		27	12	still
—12		2		grand 2
—15		5		an arch 2
Mar. 5		23	8	still
—6		24	9	still
—13		1		still 2
—30		18	3	fine, high 2
Apr. 5		24	9	still
—9		28	13	active 2
—14	12	5		still 1

General observations on the Auroræ *before October* 13, 1792.

IN making observations upon any phenomenon in nature, with a view to ascertain its cause, every particular circumstance should be attended to ; for, though many may be

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found

* A more particular account of the succeeding ones will be given hereafter.

found afterwards to be trivial, and of little or no moment in
leading us towards the discovery, yet some one or other of
them generally happens to be of importance   It will be
seen hereafter, that the exact bearing and extent of the large,
still, horizontal arch of the *aurora*, and the point in the hea-
vens to which the coruscations tend, are amongst the cir-
cumstances of much importance in the investigation of its
cause,   These circumstances, it must be confessed, were not
accurately noticed, either at *Kendal* or *Keswick*, previous to
the middle of October, 1792

   As for myself, the only minute I usually made upon the
still aurora was, that it was situate in the NW by which I
meant that its centre was between the N and the W, with-
out once attempting to ascertain the exact bearing of the
centre , and the *corona*, when there was one, is often men-
tioned in my notes, as being south of the zenith, but the
number of degrees was not ascertained.

   Mr. *Crosthwaite*, however, has been rather more particular
at times with respect to the bearings, extent, &c   The
centre of that on January 10, 1788, he observes bore NNW ;
that of the 28th of April, NW. b N ; the centres of all
the rest are said to have been between the North and West,
or else North , not one was observed to have its centre to
the East of the meridian,

   *N B. The additional observations on the Aurora, beginning
with that on the 13th of October, 1792, will be given after the
next Section.*

SECTION TWELFTH.

On Magnetism, and the variation of the Needle.

IN order to understand the additional obfervations, and the fubfequent Effay on the *aurora borealis*, a competent knowledge of magnetifm is requifite; and as the principal facts relating to that fubject are few and fimple, we have thought it would not be amifs to ftate them here, for the fake of fuch as may not be previoufly acquainted therewith.

The *Loadftone*, or *natural Magnet*, is a mineral production, found in the bowels of the earth, amongft rich iron ores, of which it is one itfelf; its diftinguifhing property is that of attracting iron and fteel. This property, which is called magnetifm, is communicable to *fteel* only, fo as to be permanent; and to *iron* when within the influence of a magnet, but as foon as the magnet is withdrawn, the magnetifm of iron ceafes.

Every magnet has two oppofite points or extremities, called its *poles;* the one is denominated its *north pole*, and the other its *fouth pole;* and the attraction of the magnet is ftrongeft at its poles.

If

If an oblong bar of tempered steel (it will answer well if 5 inches long, half an inch broad, and a quarter of an inch thick) be rubbed over from one end to the other, always the same way, by either pole of a magnet, it will be converted into a magnet itself, and that end to which the pole was first applied, will be a pole of the new magnet, of the same name as the generating pole. By rubbing the new magnet the contrary way, with the same pole, its magnetism will be first destroyed, and then fresh magnetism will be communicated; but the poles of the new magnet will be of contrary names to what they were before.

Either pole of a magnet attracts iron, or steel not magnetic; but the pole of one magnet, *repels* the pole of another magnet, of the same name, and *attracts* the pole of a contrary name; the repulsion in the former case seems to be equal to the attraction in the latter.

Magnetism is sometimes communicated, destroyed, or inverted, by lightning, or by an electric shock, &c.

If a magnetic bar, or needle, be suffered to move freely in an horizontal plane, it will only rest in one position, when the north pole points northward, and the south pole southward.— Hence the common needle and compass, which

was invented about the beginning of the 14th century.

If a plane perpendicular to the horizon be conceived to be drawn through the horizontal needle, when at reft, it is called the plane of the magnetic meridian; and the angle made by this plane, with the plane of the true meridian, is called the *variation of the needle.*

If a magnetic needle be nicely poifed on an axis paffing through its centre of gravity, or middle, and fuffered to move freely both horizontally and perpendicularly, it will reft only in one pofition, namely, when in the plane of the magnetic meridian, and having its north pole pointing towards the ground; the angle of deflection from the horizontal plane, is called the *dip* of the needle, and the needle itfelf in this cafe a *dipping-needle;* its pofition is the proper and natural one of every magnet that is fuffered to be guided folely by the magnetic influence. From this phenomenon, and others of the fame nature, it is inferred, that the earth itfelf is a magnet; whether its magnetifm refults from the united influences of the natural magnets it contains, or whether its magnetifm may be in its atmofphere, is not certain; and as poles of unlike denominations attract each other, the fouth pole of the earth's magnetifm muft be in the northern hemifphere, becaufe it attracts the north pole of the needle.

The

The variation of the needle is very different at different places of the globe, and even at the fame place at different times, in thefe parts it is at prefent wefterly, and is increafing every year, the variation at *London* in 1580 was 11° 15′ E in 1657 it was 0° 0′; at prefent, 1793, it is about 22°¼ W. and increafes nearly 10′ each year. From the refult of feveral obfervations I find it to be 25° W. at this time, at *Kendal*.

The dip of the needle too is very different at different places, and probably at the fame place at different times; but, for various reafons, the obfervations on this head are neither fo numerous nor fo accurate as thofe of the variation. It feems at prefent to be about 72° at *London*, according to Mr *Cavallo*, and there is reafon to fuppofe, it is not many degrees different in any part of *England*, for want of proper inftruments I have not been able to afcertain it at this place.

Befides the annual change in the variation of the needle, there is a daily change, or variation of the variations. According to Mr. *Canton*, who made a feries of obfervations on the daily variation for a long time, the north pole of the needle moves gradually weftward till 2 or 3 P. M. and then returns gradually to its former ftation; the mean daily variation in winter is about 7′, and in fummer about 13′¼. He moreover obferved, that the needle was difturbed when an *Aurora borealis* was in the atmofphere.

I have

I have myfelf made a like feries of obferva-
tions for fome months, and find them in general
to agree with his; but as it is not neceffary for
my purpofe to relate the refult of them, any fur-
ther than what is contained in the fubfequent
pages, I fhall not detain the reader longer on
the fubject.

Addenda *to the Obfervations on the Auroræ Boreales.*

1792.

OCTOBER 13. At *Kendal,* A. M. frequent gleams.
P. M. hazy; from 4 till 8 rainy, at which time the clouds
to the *fouth* were remarkably red, and afforded fufficient
light to read with, though there was no moon, nor light in
the north. The unufual appearance raifed my curiofity,
and I waited with impatience to fee the clouds carried off
to the SE. (for the wind was W. or NW. and pretty frefh).
In the mean time, having by me a very good *theodolite,* made
by *Dollond,* I took it out to make obfervations on the bear-
ing, altitude, &c. of any remarkable appearance.

From 9½ to 10 P. M. there was a large, luminous, hori-
zontal arch to the fouthward, almoft exactly like thofe we
fee in the north; and there was one or more faint, concen-
tric arches northward.—It was particularly noticed, that
all the arches feemed exactly bifected by the plane of
the magnetic meridian. At half paft 10 o'clock, ftreamers
appeared very low in the SE. running to and fro from W.
to E, they increafed in number, and began to approach the

K   zenith,

ze nith, apparently with an accelerated velocity; when, all on a fudden, the whole hemifphere was covered with them, and exhibited fuch an appearance as furpaffes all defcription. —The intenfity of the light, the prodigious number and volatility of the beams, the grand intermixture of all the prifmatic colours in then utmoft fplendor, variegating the glowing canopy with the moft luxuriant and enchanting fcenery, afforded an awful, but at the fame time; the moft pleafing and fublime fpectacle in nature   Every body gazed with aftonifhment, but the uncommon grandeur of the fcene only lafted about one minute, the variety of colours difappeared, and the beams loft their lateral motion, and were converted, as ufual, into the flafhing radiations, but even then it furpaffed all other appearances of the *aurora*, in that the *whole* hemifphere was covered with it.

Notwithftanding the fuddennefs of the effulgence at the breaking out of the *aurora*, there was a remarkable regularity obfervable in the manner —Apparently a ball of fire ran along from E to W and the contrary, with a velocity fo great as to be but barely diftinguifhable from one continued train, which kindled up the feveral rows of beams one after another; thefe rows were fituate one before another with the exacteft order, fo that the bafes of each row formed a circle croffing the magnetic meridian at right angles, and the feveral circles rofe one above another in fuch fort that thofe near the zenith appeared more diftant from each other than thofe towards the horizon, a certain indication that the real diftances of the rows were either nearly or exactly the fame. And it was further obfervable, that during the rapid lateral motion of the beams, their direction in every two neareft rows was alternate, fo that whilft the motion in one row was from E to W. that in the next row was from W. to E

The point to which all the beams and flafhes of light uniformly tended, was in the magnetic meridian, and, as near as could be determined, between 15 and 20° fouth of the zenith —The *aurora* continued, though diminifhing in fplendor, for feveral hours   There were feveral meteors (falling ftars)

ftars) feen at the time; they feemed below the *aurora*, and unconnected therewith.——It was feen at *Kefwick, Leeds,* &c. with much the fame circumftances; but how far it extended I have not learned.

The variation of the needle during the *aurora*, was not noticed.

Oꞓtober 14. I did not notice the *aurora* myfelf this evening; there was thunder and lightning, both here and at *Kefwick*, at the time of the *aurora*.

Oꞓtober 18. At Kendal. The *aurora* this night was an oblong, luminous cloud, about 15 or 20° long, and 4 or 5° broad, bearing about SE. by E. and 10 or 20° above the horizon; its foutherñ extremity was higher than its northern, and it evidently lay in the traꞓt of a great circle from E. to W.—It difappeared feveral times, and reappeared again almoft inftantly; and feveral times waxed and waned without vanifhing; no radiations fhot from it.

Oꞓtober 23. At Kendal. The *aurora* this evening appeared as an arch in the north-weft quarter, from which proceeded feveral beams; they converged to a point on the magnetic meridian, about 18° beyond the zenith.

Oꞓtober 31. At Kendal. A few beams were feen to run to and fro from E. to W. low, or near the horizon: the moon fhone bright at the time, and the clouds coming on foon after, the whole was obfcured.

November 19. At Kendal, the particulars of the obfervation were miflaid; at Kefwick, the *aurora* rofe to about 18° above the horizon, and was fituate in the ufual quarter.

December 7. At Kefwick, a faint appearance; about 5° high.

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January 11. At Kendal, a fmall arch in the horizon; it rofe to 5 or 10° altitude, and was bifeꞓted by the magnetic meridian.

January 12. At Kendal, from 6 to 9 P. M. a horizontal, luminous arch, 20° altitude, and bifeꞓted by the magnetic

meridian.

meridian   After 9, fine ſtreamers ſtruck out, and ran to,
and fro a while acroſs the ſaid meridian, and then were con-
verted into flaſhes, as uſual; ſome roſe up to the zenith
The point of convergency, and every other particular, were,
to all appearances, the ſame as have been deſcribed before.

The needle was conſiderably agitated at the time.

January 13. At Kendal, very bright in the northern ho-
rizon, but clouded above.——The variation of the needle at 6
P. M. 25° W , at 9 P. M. 24° 34′; at 10 P. M 24° 54′;
next morning 25° 4′

February 8 At Kendal, bright northward at 8½ P. M.
at 10, the luminous arch was 16° altitude.——The other cir-
cumſtances relating to it follow, ſuppoſing the variation of
the needle at the noon of that day 25° W

H M	Variation of the needle.	
10 — P. M	25° 0′ W	the arch riſing
10 10 ——	24 54 —	bright ſtreamers, low, with clouds.
10 30 ——	24 42 —	ſtreamers riſen , fine, weſtward*.
10 35 ——	24 37 —	a ſtill light , clouded above.
10 45 ——	24 57 —	bright, eaſtward ; clouds above
10 55 ——	25 7 —	light equal, eaſt and weſt
11 5 ——	25 7 —	bright, low , clouded above.
11 15 ——	24 57 —	clouded, but bright eaſtward.

It was related to the magnetic meridian as the former ones.

February 12 At Kendal, the *aurora* appeared ſoon after
6 P. M flaming over two-thirds of the hemiſphere. The
beams all converged to a point in the magnetic meridian,
about 15 or 20° to, the ſouth of the zenith, as was found
from frequent trials —The other particulars follow.

H M	Variation.	
5 — P. M	25° 5′ W.	
6 35 ——	24 49 —	altitude of the clear ſpace ſouth 35°.
6 42 ——	24 55 —	alt. of do. 20°, ſtreamers bright, eaſt.
6 50 ——	25 — —	
7 2 ——	25 28 —	ſtreamers bright and active all over
7 5 ——	25 12 —	the illuminated part.

H.

* That is, relative to the magnetic meridian, here and elſewhere.

H. M.   Variation.

7 10 P. M. 24°40′ W. diſappeared in the weſt; active, eaſt.

7 15 —— 24 40 ——

7 20 —— 24 35 —— active about the zenith; light faint.

7 25 —— 24 45 —— light faint.

7 35 —— 24 45 —— light faint.

8 —— —— 24 45 —— ſtrong light northward.

8 10 —— 24 45 —— ⎫ a large, uniform, ſtill light, cover-
8 35 —— 24 47 —— ⎬ ing half the hemiſphere, with
                      ⎭ flaſhes now and then.

9 15 —— 24 43 —— ſtreamers NW. bright, eaſt; clouds.

9 20 —— 24 43 —— the *aurora* burſting out afreſh.

9 30 —— 24 50 —— ⎫ as fine and large a diſplay of ſtream-
10 —— —— 24 55 —— ⎬ ers as has appeared this evening.

10 15 —— 24 57 —— ⎫ the light growing fainter and
10 35 —— 24 40 —— ⎬ fainter.

  8 —A.M. 24 57

N. B. The arch bounding the *aurora* to the ſouth, was always at right angles to the magnetic meridian, when perfect.

At Keſwick, the ſame evening; 7 P. M. ſtreamers from ENE. to WSW. and 28° paſt the zenith; perpendicular beam bore N. 17° W.—At 9h 25m very fine; they converged to a point 15° ſouth of the zenith, bearing SSE.—Altitude of clear ſpace 30°. The perpendicular beam N. 35° W.; extent on the horizon from ENE to WSW.—At 10h 30m they were ſettled in the northern quarter into an arch of 13° altitude, whence ſtreamers ſhot up towards the zenith.

February 15. The *aurora* of this evening was ſeen both at Kendal and Keſwick, and, as far as the eye could judge, the appearances ſeem to have been the ſame at both places.—It was a luminous arch, the centre of which bore SSE.; and it was extended in the oppoſite directions of ENE. and WSW.: on the weſt ſide its extremity ſeemed to touch the mountains at both places, at the altitude of 6°; and on the eaſt ſide it extended about half way to the horizon. The eaſtern end was rather ovaliform, about 8 or 10° broad, and

where

where it joined to the reft, was narroweit of all, being but
2 or 3° broad, and bearing SE , after which its breadth
increated towards the welt, being in fome places 6 or 8°.
—The fky was clear, and there was no appearance of an
aurora in the north, except two or three fmall ftreamers at one
time, quite in the horizon   The eaftern end of the arch
waxed and waned frequently, and fometimes entirely vanifh-
ed, and then reappeared again, in the fpace of a few feconds.
About a quarter palt 10 it grew faint, and finally difappeared.
It did not fenfibly vary in pofition during its appearance,
and juft before it vanifhed, its fituation amongft the ftars, as
feen from Kendal, was as follows —the fouth edge of the
arch feemed to touch pretty exactly the ftar *lucida colli*, or
gamma Leonis, to pafs 4 or 5° above *Procyon*, thence through
the middle of the conftellation *Orion*, leaving his bright foot,
Rigel, 2 or 3° to the fouth.

From thefe obfervations it refults, that the greateft alti-
tude of the edge, at Kendal, muft have been about 53°
Mr *Crofthwaite* found the greateft altitude of the faid edge,
at Kefwick, to be 48°. The diftance of the two places, as
has been obferved, is about 22 Englifh miles, and it fortu-
nately happens, that they lie very nearly in the direction of
a plane at right angles to the arch ; hence, we have the re-
quifite *data* to determine the height of the arch, which, by
trigonometry, comes out 150 Englifh miles.

The parallactic angle being fo fmall, an error of 1 or 2°
in the altitudes, is of great confequence —Mr. *Crofthwaite*
thinks the error in his obfervations could not exceed $1°\frac{1}{2}$,
as the light was fteady at the place where the altitude was
taken.—Admitting the errors amounted to 2° at each place,
which exceeds the bounds of probability, and that they were
contrary , we fhall then find the height 83 miles in the one
cafe, and 750 in the other, which may, I think, be fafely
confidered as boundaries, betwixt which the true height
was , and hence it may be infered, that the arch would be
vifible to all *Great-Britain* and *Ireland,* that it is much to be
wifhed, fome perfons in more diftant places, may have made
                                                        fimilar

fimilar obfervations upon the phenomenon, by which its height may be determined with more precifion —In the mean time we fhall confider it as 150 Englifh miles.

March 5. The *aurora* at Kendal was feen at 8 P. M. ; it was a bright ftill light a while, but foon clouded.——The needle was not attended to.

March 6. At Kendal, a few fine ftreamers at 9 P. M. altitude 15°, and extent along the horizon 70° ; exactly bi-fected by the magnetic meridian. It foon dwindled into a faint light. At 9h 35m brighteft on the northern fide.—— The needle was 25° at 9h 4m,—24° 58´ at 9h 14m,—24° 50´ at 9h 35m,—24° 55´ at 10h 30m,—24° 52´ at 8 the next morning.

March 13. At Kendal the needle was at 8h 30m 24° 30´, —at 10h 30m 25° 4´,—and at 8 next morning 25° 4´.—— There was a brightnefs northward at 10 P. M. but pretty much clouded ; this circumftance, with that of the needle, rendered it probable an *aurora* was in the atmofphere.—— It was confirmed by the following account.

At Kefwick, the fame evening, at 8h 18m a horizontal arch, extent from NW. by W. to NNE. with faint ftreamers ; the arch 20°, and ftreamers 25° altitude ; the vertical ftreamers bore NNW. At 10, an arch from WSW. to ENE. its greateft altitude 30° : no ftreamers.

March 30. At Kendal, at 8 P. M. there appeared fome faint concentric arches of an *aurora* ; it was not further no-ticed till,

H. M.		Variation.	
8 35 P. M.	25°	5´ W.	a grand horizontal arch, altitude 6°.
8 40 ——	25	25 —	ftreamers to 30° paft the zenith.
8 48 ——	25	5 —	bright eaftward.
8 55 ——	25	5 —	ftreamers faint.
9 ——	25	5 —	denfe light north ; rare above.
9 5 ——	25	10 —	ditto
9 10 ——	24	55 —	bright weftward.
9 15 ——	24	55 —	a fine, perfect, horizontal arch.
9 20 ——	24	55 —	altitude of its upper edge 30°.

H.

Addenda *to the*

H.	M.	Variation.	
9	30	P. M. 24°30′	W. ſtreamers up to the zenith.
9	35	—— 24 35	— diſperſed, and not ſo high.
9	45	—— 24 58	— faint light; brighteſt eaſtward.
9	52	—— 24 45	— dull light.
10	——	—— 24 42	— dull light; haze below.
10	10	—— 24 42	— haze riſen; light fainter.
10	15	—— ———	— clouds riſen; light almoſt vaniſhed.
10	30	—— 24 45	— clouds more riſen.
11	15	—— 24 45	— ſeveral ſmall clouds cover the hemiſ-
8	—A. M.	24 54	[phere.

There were ſeveral fine, perfect, concentric arches north-
ward, during moſt of the time.—At 8h 48m one fine arch,
the altitude of its under edge 10°. At 8h 55m two perfect
arches, altitude of the higher 12°, with a fine edge. At
9h ſeveral concentric arches, one with a fine edge, altitude
11°. At 9h 5m one of the upper arches with a very bright
edge, its altitude 13°; the baſes of the ſtreamers compoſing
it of very denſe light, and rare above. At 9h 10m its alti-
tude 13 or 14°.—At 9h 15m the upper edge of the large
horizontal light ſeems now as well defined as that of a rain-
bow, its altitude 47°, and that of the under edge 10°.
At 9h 20m altitude of upper edge 30°.

The arches were all at right angles to the magnetic meri-
dian, and the beams had their uſual convergency.—At one
time ſeveral ſmall ſtreamers formed a *corona* upon the mag-
netic meridian, the centre of which was determined by a
good obſervation to be 72° from the ſouth.

The ſky was free from clouds till the laſt.

At Keſwick, the ſame evening, at 8h 20m there were
bright ſtreamers WNW.—At 8h 28m they had ſpread from
WSW. to ENE.; altitude of the arch 14°; vertical ſtream-
ers bore NW. by N. At 8h 35m ſtreamers 43° paſt the ze-
nith*: previous to this there were at one time three con-

<div align="right">centric</div>

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* By the obſervations at *Kendal*, the *aurora* was 30° paſt the zenith at
8h 40m, and the clocks being corrected at both places, ſo as to be near
<div align="right">the</div>

centric arches northward, fet with bright ftreamers, which had a very quick lateral motion; the under edge of the higheft was not more than 14° high. At 9h 6m the altitude of the faid arch was 13°½, bearing NW ¼ N , ftreamers fhort, being only 5° higher than the under edge; horizontal extent of the arch from W. by N to NE.

April 5. At Kendal, a fmall blufhing of light, exactly in the magnetic north, at 9 P M , it foon faded away.

The difturbance of the needle was imperceptible

April 9. The *aurora* was firft feen at Kendal, at 9h 30m P. M being a fmall blufhing of light in the magnetic north. At 10h the arch rifen to 6 or 8° of altitude, with ftreamers from 3 or 4 to 10° altitude, and a mift below , the reft of the fky was extremely clear , the light was denfe at the under edge of the arch. At 10h 25m bright and active weftward , the mift below —Soon after, uncommonly active ftreamers, very low , the light feen denfe through the mift. At 10h 35m the mift vanifhed, the *aurora* rather larger, and duller   At 11h a larger arch, altitude 10°, with mift below , no ftreamers, the light being ftill and uniform.   At 11h 10m ftreamers very active , then progrefs feemed down, or northward.

The needle was not fenfibly difturbed all the while.

At Kefwick, the fame evening, a faint light at 9h 45m. —It was 7° high at 9h 54m, and the higheft part bore N. by W. ½ W , one minute after, bright ftreamers from NE. to WNW. the greateft altitude of their bafe 5°⅓, the bearing of the fame NW. by N. ¼ N.—From this to 10h 30m, bright ftreamers at intervals, low in the NW quarter.— After 10h 30m grown faint ; horizontal extent from WNW. to NE. by N.

April 14. At Kefwick, about midnight, or foon after, a ftill, horizontal light, altitude of the under edge 5°, of the upper edge 9°½; bearing of the centre NW. ¼ N.

<center>L</center>

the true folar time, it is prefumed this obfervation would be almoft cotemporary with that at *Kendal* ——Now, fuppofing this to be the cafe, the height of the *aurora*, or of the lower extremity of the beams, will be found equal to 62 Englifh miles.

GENERAL OBSERVATIONS;

IN order to determine the bearings of the middle or highest part of the arches of the *aurora*, I placed myself in a station where I had a distant object before me, in the direction of the magnetic meridian, and I always found the highest part in the same direction as this object ;—a deviation of 2 or 3° would in most cases have been very sensible. —Sometimes, to confirm the observation, equal altitudes of the arches were taken on each side of the magnetic meridian, with the theodolite, and the horizontal angle divided into two equal parts, which gave the same bearing of the centre as the other method.—It does not, however, always happen that the horizontal arch, especially when high, is perfect and complete.

The streamers, or flashes, which pointed up, or perpendicular to the horizon, were only those in the magnetic meridian, as well south as north of the zenith.

The altitude of the centre of the *corona*, when there was one formed, was taken with a quadrant and plummet, with as much exactness as the thing seemed to admit of.

With regard to the needle of the theodolite, which was used to make the observations with, it is $3\frac{1}{2}$ inches long, and seems to move very freely upon its centre ; I have often tried the effect of friction, by drawing it from its station, and then suffering it to vibrate till it settled, when it usually settled in the same station within one or two minutes, but I have sometimes observed it *five* minutes of a degree altered in such a case.

I have never observed any considerable fluctuation of the needle in any evening but when there was an *aurora* visible, except once ; this was on the 13th of February, 1793, the evening of which was very wet and stormy ; the needle va-

ried

ried as follows —the variation was 24° 57′ at noon; 24° 35′ at 5¾ P M , 24° 35′ at 5h 50m, 24° 20′ at 5h 58, 24° 20′ at 6h , 24° 48′ at 6h 20m, 24° 45′ at 6h 45m; 24° 35′ at 8h , 24° 47′ at 8h 30m, 24° 49′ at 10h 30m; 24° 53′ at 8 A. M. next day.

N B. There had been an *aurora* the preceding evening.

It fhould alfo be noticed, that whilft making thefe ob-fervations upon the difturbance of the needle, during an *aurora*, I did not always know the *abfolute* variation at the time , and therefore no inferences fhould be made relative to the change in the abfolute variation, in the interval from one *aurora* to another, from the obfervations I have given.

END OF THE FIRST PART.

METEOROLOGICAL

OBSERVATIONS AND ESSAYS.

PART SECOND.

ESSAYS.

ESSAY FIRST.

On the Atmosphere; its Constitution, Figure, Height, &c.

THE atmosphere is that invisible, elastic fluid which every where surrounds the earth, to a great height above its surface.——It was formerly supposed, that common air, or any portion of the atmosphere, when cleared of vapours and exhalations, was a pure, simple, elementary fluid; but modern philosophy has demonstrated the contrary, and it now appears that the purest air we breathe at any time, consists of an intimate mixture

mixture of various elaſtic fluids, or *gaſſes*, in different propoitions. Thoſe properties of the atmoſphere, called its ſalubrity and inſalubrity, depend principally upon the greater or leſs quantity of one of its conſtituent principles, *vital* or *dephlogiſticated* air.—Whether the ſuperior regions of the atmoſphere conſiſt in like manner of various elaſtic fluids, or whether the fluids are the ſame or different from theſe below, cannot, from the nature of the caſe, be determined experimentally.

The figure of the exterior ſurface of the atmoſphere would, from the principles of gravitation, be ſimilar to that of the earth, or of an oblate ſpheroid; or, its height and quantity of matter about the equator, would be ſomething greater than at the poles, to preſerve an equilibiium every where, owing to the centrifugal force, which is greateſt at the equator. The denſity of the atmoſphere, ſuppoſing it of an uniform temperature, and alike conſtituted every where, would decreaſe in aſcending, in a geometrical progreſſion: thus, if the denſity at one mile high was 1, and that at four miles high $\frac{1}{2}$; then that at ſeven miles high would be $\frac{1}{4}$, at ten miles high $\frac{1}{8}$, &c.——I ſay theſe circumſtances *would be*, were it not for the ſun, or the principle of heat which it ſeems to produce; but by means of the unequal diffuſion of this principle, the circumſtances are very materially different.

<div align="right">Tha</div>

The mean annual temperature of the air, at the earth's surface, decreases in going from the equator to the poles. Mr. *Kirwan* * states the mean annual heat at the equator at 84°, and that at the pole at 31°. Moreover, the temperature of the air over any place, in clear, serene weather, decreases in ascending above the earth's surface, nearly in an arithmetical progression, and at the rate of 1° for every hundred yards. Experience proves this, as far as to the summits of the highest mountains, which is about 3 miles; and hence it may be inferred to be so above that height.

The great heat in the torrid zone rarefies the air, by increasing its elasticity; consequently the equilibrium of the atmosphere is disturbed. The rarefied air ascends into the higher regions, where, meeting with little resistance, it must flow northward and southward; the pressure upon the northern and southern regions is thus increased, and a current must set in below, towards the equator, to restore the equilibrium.—— Hence, the higher temperature within the torrid zone, swells the atmosphere there, and raises it, or at least the gross parts of it, to a much greater height than elsewhere; whilst in the frigid zone it is contracted by cold.—This is the effect of the different temperatures at the earth's surface: but the increase of cold in ascending destroys the

the law of decreafe in denfity above mentioned, and greatly contracts the height of the atmofphere, as deduced from fuch law; though this circumftance has perhaps no effect upon the figure of the atmofphere.

Philofophers have attempted to find the height of the atmofphere by two methods; namely, by the duration of twilight, and by experiments upon the defcent of the barometer on high mountains. The former determines the height about 45 miles, as follows:—the twilight difappears when the fun is 18° below the horizon; hence it is argued, that a ray of light emitted from the fun, fo as to be a tangent to the earth's furface, after paffing through the atmofphere, is reflected from its external furface fo as to be a tangent to the earth's furface again, at 18° diftance from the former place of contact. This argument being admitted, affords *data* to find the height of the atmofphere, a proper allowance for refraction being firft made.—Several objections to this conclufion however may be ftated; amongft others, it may be faid, we do not know whether the light, which comes to us at the dawn or departure of day, has been once or twice reflected; it may, and probably does, proceed from the zone of the earth illuminated by the twilight itfelf; in this cafe, therefore, we can determine no more from the twilight, than that the height of the atmofphere, or of that

region

region of it which is denfe enough to reflect light, is not fo much as 45 miles.

Barometrical experiments afford a much furer approximation to the height of the atmofphere, or rather perhaps of the more grofs and heavy parts of it. From thefe we are affured, that a *ftratum* of air reaching from the earth's furface to the height of 4 Englifh miles, at all times contains above *one half* of the quantity of matter in the whole atmofphere; and by extending the laws thence refulting, we infer, that a *ftratum* 12 or 13 miles high, contains $\frac{38}{39}$ths of the whole: or, if a barometer, ftanding at 30 inches, was elevated to that height, the mercury would fall 29 inches.

The following table and theorem, extracted from Sir *George Shuckburgh*'s letter to Col. *Roy*, (Philofophical Tranfactions, Vol. 68.) will ferve to give my readers an idea in what manner the barometer is made fubfervient to the purpofe; and alfo how the height of mountains, &c. may be afcertained by means of the barometer.——In order to underftand the ufe of the table, it fhould be obferved, that two perfons are to take cotemporary obfervations, upon two barometers and thermometers, one perfon having one of each at the bottom of the mountain, and the other at the top.

EXPLANATION.

This table gives the number of feet in a column of the atmofphere, equivalent in weight to a like column of quickfilver $\frac{1}{10}$th of an inch high, when the barometer ftands at 30 inches, for every 5° of temperature from 32 to 80*.—For any other height of the barometer it will be in the inverfe ratio of that height to 30——Let $A =$ the mean height of the two barometers, in inches;

The Table.	
Thermometer	Feet
°	
32	86 85
35	87.49
40	88 54
45	89 60
50	90 66
55	91 72
60	92.77
65	93.82
70	94.88
75	95 93
80	96 99

$a =$ the difference of the two, in tenths of an inch, $b =$ the number of feet, per table, correfponding to the mean height of the two thermometers; $x =$ the height of the mountain, in feet: then, we fhall have this theorem, $\frac{30ab}{A} = x$, the height required.

EXAMPLE.

Suppofe the barometer at the bottom to be 29.72 inches, thermometer 64°; the barometer at the top 27.46, thermometer 58°; required the height of the mountain?

Here the mean height of the two barometers, or $A = 28.59$ inches; their difference in tenths

M   of

* From the table it appears, that, in round numbers, every 30 yards of elevation reduces the height of the mercury in the barometer $\frac{1}{10}$ of an inch, near the earth's furface.

of an inch, or $a = 22.6$; the mean heat of the
two thermometers $= 61°$; the proportional
number may be found from the table $= 92.98$
feet $= b$; hence, $\dfrac{30 \times 22.6 \times 92.98}{28.59} = 2205$ feet,
the height required.

From this theorem we can deduce another :—
supposing the elevation of the upper barometer
given, and the height of its mercurial column
required; the other *data* as before.——Let H
$=$ the height of the barometer below. in inches;
$b =$ the number of feet, per table, as before [*];
$p =$ the perpendicular elevation of the upper
barometer, in feet; $y =$ the height of its mer-
curial column, in inches: then, we obtain this
theorem, $y = \dfrac{600b - p}{600b + p} \times H$.

Hence we may calculate the height of the
mercurial column of the barometer at any given
moderate elevation, and by repeating the pro-
cess, for a larger also, sufficiently accurate for
the purpose of explaining the theory of the va-
riation of the barometer; though we cannot
from this fix the boundary of the atmosphere
with precision. To what height the very thin
and rare medium in the higher regions rises,
we cannot ascertain; but there is sufficient rea-
son

[*] The height of the thermometer below being given, the
height of that supposed above may be estimated, by deduct-
ing 1° for every hundred yards of elevation.

fon to conclude, as will be feen in a fubfequent
Fflay, that it extends to a much greater height
than has commonly been fuppofed.

The following table contains the refult of a
calculation from the laft mentioned theoem, of
the height of the mercurial column, at certain
elevations, above the equator, and likewife over
the north of *England*, and the north pole. The
mean heat at the earth's furface, under the e-
quator, is fuppofed 84°; the mean heat in thefe
parts, for the hotteft month of fummer, at 60°,
and for the coldeft month of winter at 35°, the
mean annual temperature at the north pole
being fuppofed 31°, the mean temperature for
the coldeft month of winter at that place may
perhaps be ftated at 2°.

Elevation of the barometer above the level of the earth in miles	Height of the mercurial column of the barometer, in inches			
	Above the equator	Above the North of England		Above the north pole
		In fummer	In winter	In winter
0	30 00	30 00	30 00	30 00
2	20 55	20 10	19 58	18 31
4	13 61	12 06	12 24	11 19
6	8 66	7 98	7 26	6.24
8	5 25	4 65	4 03	3 19
10	3 00	2 52	2 05	1 45
12	1.58	1 24	93	56

ESSAY

ESSAY SECOND.

On Winds.

WINDS have ever been confidered, with reafon, as having a principal fhare in producing changes of weather, and therefore they demand a particular regard in meteorology.

Moft people know that the winds are not every where fo changeable as in thefe parts. In the torrid zone, the winds are much more uniform in direction than they are either in the temperate or frigid zones: over the Atlantic and Pacific oceans, particularly between 30° of north and 30° of fouth latitude, the *trade winds*, as they are called, blow pretty uniformly from eaft to weft, all the year round, with a fmall variation in the different feafons.

The caufe of thefe conftant winds, within the tropics, the ingenious and learned Dr. *Halley* has endeavoured to explain, and his explication feems to have been univerfally adopted by others fince its publication.—The chief phyfical principle he ufes, is the undeniable and well known one, that the air is rarefied by heat; and, as the earth, in revolving from weft to eaft, expofes the torrid zone every day to the direct rays of

the

the fun, the earth, and confequently the air, is there moſt heated ; the *maximum* of heat follows the fun, and therefore moves in a contrary direction, or from eaſt to weſt ; the rarefaction occaſioned thereby diſturbs the equilibrium of the atmoſphere fucceſſively ; and he argues, that a current of air will conſtantly follow the extreme of heat, to reſtore the equilibrium,—and thus he accounts for the trade winds.

It appears to me, however, that this concluſion is premature, and not warranted by the laws of motion. For, to ſimplify the conception, let us ſuppoſe a ring with a number of beads arranged upon it at equal diſtances, and, abſtracting from the force of gravity, that each of them is endued with a repulſive power, in the ſame manner as are the particles of air. This fuppoſition being made, let the principle of heat, or any other power, which acts ſimply by increaſing their elaſticity, act upon them in one part of the ring more than in another ; this will of courſe ſeparate the particles in ſuch part farther than they were before, and condenſe the others ; but it can never produce a rotary motion of the whole number of them round the ring, becauſe the action being mutual, the motion generated muſt be equal and contrary ;—or, in other words, no momentum of the whole maſs of particles around the ring, can be produced by any forces, which they exert upon each other, agreeably to *Newton*'s

ton's third law of motion.—We have here suppofed the heat applied to one part of the ring only, but it is plain the fame conclufion will obtain if it be applied to feveral parts at the fame time, or fuccefively, or in any other manner; likewife if the *addition* of heat produce no momentum, the *abftraction* of it will not.

Now to apply this to the matter in queftion: let the fun be upon the equator, and the air underneath be heated; then the air in the plane of the equator cannot recede from that plane, becaufe the lateral preffure on each fide will be equal; and the action of the particles in the faid plane upon each other, will be in the fame circumftance as that of the particles upon the ring, with refpect to any horizontal motion that may be produced in the plane by the heat of the fun. It appears then, that no rotary motion of the air round the earth can be produced by the action of the fun upon the particles in that plane; and by a like method of reafoning it may be proved, that no fuch motion can be produced in any other parallel plane; confequently, the caufe we are fpeaking of, or the fuccefive rarefaction of the air from eaft to weft, cannot produce the effect in queftion, nor immediately contribute thereto.

It will be afked, if the trade winds are not produced by the fuccefive rarefaction of the

parts of the atmofphere within the torrid zone, what are they produced by ?—To this it may be replied, that they admit of an explanation upon mechanical principles without requiring any hypothetical reafoning, or any other phyfical principle than that Dr. *Halley* ufes ; namely, that heat rarefies the air. The inequality of heat in the different climates and places, and the earth's rotation on its axis, appear to me the grand and chief caufes of all winds, both regular and irregular ; in comparifon with which all the reft are trifling and infignificant. The trade winds in the torrid zone, and the variable winds every where elfe, feem to be the natural effects of thefe two caufes, and might have been deduced from them *a priori*, if the facts had never been afcertained by the navigation of the torrid zone. Notwithftanding, as we are in poffeffion of many facts relative to the winds, it may be proper firft to ftate them, and then to confider how they refult from the caufes above mentioned.

Facts relating to the Winds.

1. Over the Atlantic and Pacific oceans, as has been obferved, the trade-winds extend from 30º of north to 30º of fouth latitude.

2. When the fun is on the equator, the trade-winds, in failing northward, veer more and more from the eaft towards the north ; fo that about their limit they become nearly NE. :

and

and, *vice versa*, in failing southward, they be-
come at last almost SE.

3. When the sun is near the tropic of cancer,
the trade-winds north of the equator become
more nearly east than at other times, and those
south of the equator more nearly south : and,
vice versa, when the sun is near the tropic of
capricorn.

4. The trade-wind is not due east upon the
equator, but about 4° to the north of it.

5. The winds in the northern temperate zone
are variable, but the most general are the SW.
and W. and the NE. and E.——See page 48.

6. In the northern temperate and frigid zones,
and doubtless in the southern also, the winds are
more tempestuous in winter than in summer.——
See page 49.

Now in order to perceive the reason of these
facts, it must be remembered, that the heat is at
all times greatest in the torrid zone, and de-
creases in proceeding northward, or southward ;
also, that the poles may be considered as the
centres of cold at all times : hence it follows,
that, abstracting from accidental circumstances,
there must be a constant ascent of air over the
torrid zone, as has been observed, which after-
wards falls northward and southward ; whilst the
colder air below is determined by a continual
impulse towards the equator.　And, in general,
wherever the heat is greatest, there the air will
ascend.

afcend, and a fupply of colder air will be re-
ceived from the neighbouring parts.———Thefe
then are the effects of the inequality of heat.

The effects of the earth's rotation are as fol-
low : the air over any part of the earth's furface,
when apparently at reft or calm, will have the
fame rotary velocity as that part, or its velocity
will be as the co-fine of the latitude; but if a
quantity of air in the northern hemifphere, re-
ceive an impulfe in the direction of the meridian,
either northward or fouthward, its rotary velo-
city will be greater in the former cafe, and lefs
in the latter, than that of the air into which it
moves; confequently, if it move northward, it
will have a greater velocity eaftward than the air,
or furface of the earth over which it moves, and
will therefore become a SW. wind, or a wind
between the fouth and weft.   And, *vice verfa,*
if it move fouthward, it becomes a NE. wind.
Likewife in the fouthern hemifphere, it will ap-
pear the winds upon fimilar fuppofitions will be
NW. and SE. refpectively *.

The trade-winds therefore may be explained
thus : the two general maffes of air proceeding

<div align="center">N</div>

from

* M. *De Luc* is the only perfon, as far as I know, who
has fuggefted the idea of the earth's rotation altering the
direction of the wind, which idea we have here purfued
more at large.—Vid. " Lettres phyfiques, &c." Tom. 5.
Part. 2. Let. cxlv.

from both hemispheres towards the equator, as they advance are constantly deflected more and more towards the eaft, on account of the earth's rotation; that from the northern hemisphere, originally a north wind, is made to veer more and more towards the eaft, and that from the fouthern hemisphere in like manner is made to veer from the fouth towards the eaft; thefe two maffes meeting about the equator, or in the torrid zone, their velocities north and fouth deftroy each other, and they proceed afterwards with their common velocity from eaft to weft round the torrid zone, excepting the irregularities produced by the continents. Indeed the equator is not the centre or place of concourfe, but the northern parallel of 4°; becaufe the centre of heat is about that place, the fun being longer on the north fide of the equator than on the fouth fide. Moreover, when the fun is near one of the tropics, the centre of heat upon the earth's furface is then nearer that tropic than ufual, and therefore the winds about the tropic are more nearly eaft at that time, and thofe about the other tropic more nearly north and fouth.

Were the whole globe covered with water, or the variations of the earth's furface in heat regular and conftant, fo that the heat was the fame every where over the fame parallel of latitude, the winds would be regular alfo: as it is, however, we find the irregularities of heat, arifing

from

from the interspersion of sea and land, are such, that though all the parts of the atmosphere in some sort combine to produce regular winds round the torrid zone, yet the effect of the situation of land is such, that striking irregularities are produced witness, the monsoons, sea and land breezes, &c. which can be accounted for on no other principle than that of rarefaction; because the rotary velocity of different parallels in the torrid zone is nearly alike —For this reason we have omitted giving the facts, and their explanation, as having been done by others.

From what has been said it might be supposed that the winds in the northern temperate zone should be between the north and east below, and between the south and west above, almost as regularly as the trade-winds, but when we consider the change of seasons, the different capacities of land and water for heat, the interference and opposition of the two general currents, the one of which is verging towards a central point, and the other proceeding from it, we might conclude it next to impossible that the winds in the temperate and frigid zones should exhibit any thing like regularity notwithstanding this, observations sufficiently evince, that the winds in this our zone are, for the most part, in the direction of one of the general currents; that is, some where between the north and east, or else between the south and west; and that

winds

winds in other directions happen only as acci-
dental varieties, chiefly in unfettled weather.

In winter, the heat decreafes more rapidly in
leaving the equator, and proceeding northward,
than at any other feafon; confequently the cur-
rents of air to and from the equator, in the
northern hemifphere, move with the greateft ve-
locity, and occafion the moft tempeftous wea-
ther, in that feafon: and, *vice verfa*, in fummer.

The effect of the earth's rotation to produce,
or rather to accelerate the relative velocity of
winds, being as the difference betwixt the co-
fines of any two latitudes, (or, to fpeak more
ftrictly, the effect is as the fluxion of the co-fine
of the latitude, the fluxion of the latitude being
fuppofed conftant) it will be fmall within the
torrid zone, and increafe in approaching the
poles. The hourly rotary velocity of the equa-
tor is about 1040 Englifh miles; if we fuppofe
it 1000 miles it will be accurate enough for our
purpofe, and then, from a table of natural fines,
the rotary velocity of any parallel may be had at
once; the differences of thefe velocities, will
ferve to give us fome idea of the comparative
effect of the earth's rotation at different parallels;
for which purpofe we have fubjoined a table,
giving the rotary velocity of the parallels of la-
titude for every 10 degrees, together with their
differences, agreeable to the above fuppofition.

<div align="right">Degrees</div>

Degrees of latitude.	Hourly rotary velocity of the parallels, in English miles.	Differences of their velocities.
°		
0	1000	
10	984.8	15.2
20	939.7	45 1
30	866	73.7
40	766	100
50	642.8	123.2
60	500	142.8
70	342	158
80	173.6	168.4
90		173.6

From the table it appears, the effect of the earth's rotation, to accelerate the relative velocity of winds, is about ten times as great at the poles as at the equator;—by *relative velocity*, my readers will perceive I mean, all along, the velocity of the wind relative to the place of the earth's surface over which it blows; hence, the relative velocity and direction of the mass of air from the equator is at first altered very slowly, and afterwards more rapidly, by the earth's rotation; and, *vice versa*, with respect to that from the poles.

Had the trade-winds been produced by the daily rarefaction of the air from east to west alone, independent of the earth's rotation, they should have extended to 50° of north latitude when the sun is at the tropic of cancer, because the heat at that parallel is then as great as at 30° of south latitude, which is quite contrary to experience: in fact, they ought to have extended,

tended, in a greater or lefs degree, over the ocean, from the equator to the poles, and the fummers have been more tempeftuous than the winters, becaufe the daily variation in heat is then greateft; neither of which we find confiftent with obfervation.

The relative velocity of winds may be beft afcertained by finding the relative velocity of the clouds, which, in all probability, is nearly the fame as that of the winds; the velocity of a cloud is equal to that of its fhadow upon the ground, which, in high winds, is fometimes a mile in a minute, or 60 miles an hour; and a brifk gale will travel at the rate of 20 or 30 miles an hour. —It may be imagined, that the relative velocity of winds fhould be continually upon the increafe, by reafon that their caufes are conftantly in action, and not for a moment only; but the refiftance which a current of air meets with from the atmofphere itfelf, and from objects upon the earth's furface, muft be very confiderable; the increafe or diminution of the relative velocity of a wind will therefore depend upon the proportion between the active caufes and the refiftance.

The œconomy of winds, an illuftration of which we have been here attempting, is admirably adapted to the various purpofes of nature, and to the general intercourfe of mankind:— had the fun revolved round the earth, and not
the

the earth on its axis, the air over the torrid zone, and particularly about the equator, would have been in effect stagnant; and in the other zones the winds would have had little variation either in strength or direction; navigation, in this case, would have been greatly impeded, and a communication between the two hemispheres, by sea, rendered impracticable. On the present system of things, however, the irregularity of winds is of the happiest consequence, by being subservient to navigation; and a general circulation of air constantly takes place between the eastern and western hemispheres, as well as between the polar and equatorial regions; by reason of which, that diffusion and intermixture of the different aerial fluids, so necessary for the life, health, and prosperity of the animal and vegetable kingdoms, is accomplished:—such is the transcendent wisdom and providential care of the common FATHER OF ALL!

PROOF OF THE EARTH'S ROTATION.

The trade-winds being matter of fact, if the mechanical principles we have explained them upon be admitted, we may draw from hence a very satisfactory, and indeed conclusive argument for the earth's rotation on its axis; for, the trade-winds blowing from east to west, we must conclude, *a posteriori*, that the earth revolves the contrary way, or from west to east.

ESSAY

ESSAY THIRD.

On the variation of the Barometer.

THE caufes of the variation of the barometer have never yet been difcovered, fo as to admit of demonftration; though feveral eminent philofophers have given the public the refult of their reafoning and experience on the fubject. We propofe to confider the principal of their allegations; but in the firft place it will be proper to lay down the chief *facts* refpecting the variation, which are the refult of obfervation, and not of any hypothefis.

Facts relating to the Barometer.

1. The barometer has very little variation within the tropics.

I believe the barometrical range has not been obferved much to exceed half an inch, in the torrid zone.

2. Within the northern temperate zone, and doubtlefs the fouthern alfo, the range of the barometer increafes in going from the equator.

The mean annual range * at *Paris*, in latitude 48° 50′ N. for 20 years, was 1¼ inch; the greateft range, or difference between the higheft and loweft obfervations, for the fame term, was 2 inches. (Vid. *Martyn's Abridgment of the Parifian*

* By *annual range*, I mean the difference between the higheft and loweft obfervations each year.

fian Memoirs). At *Kendal*, in latitude 54° 17′ N. the mean range for 5 years was 2.13 inches; the greateft range was 2 65 inches. A comparifon of the obfervations made at *London*, *Kendal*, and *Kefwick* likewife corroborates the fame. —In *Sweden*, and *Ruffia*, the range is ftill greater.

3. In the temperate zones the range and fluc-tuation of the barometer is always greater in winter than in fummer.

See the obfervations, particularly the tables, p. 16 and 17.

4. The rife and fall of the barometer are not local, or confined to a fmall diftrict of country, but extend over a confiderable part of the globe, a fpace of two or three thoufand miles in circuit at leaft.

See the general obfervation, page 16.

In the French Philofophical Tranfactions for 1709, there is a comparifon of obfervations upon the barometer made at *Paris* and *Genoa*, for 3 years; the diftance of the places is at leaft 350 miles; notwithftanding this, it was found to rife and fall almoft univerfally on the fame day at both places, only the variation was lefs at *Genoa* than at *Paris*, becaufe its latitude is lefs; no difference in time was perceived, whether the fluctuations were fudden or gradual, except in one inftance, when the rife was one-day later at *Genoa* than at *Paris*.

The precife extent to which the fluctuations of the baro-meter reach, has not, that I know of, ever yet been afcer-tained in any one inftance, for want of cotemporary obfer-vations made at a great number of diftant places.

5. The barometrical range is greater in *North America* than in *Europe*, in the fame latitude.

From the American Philofophical Tranfactions we find the range is as great in *New England* as in this country, though it is 10° nearer the equator. Alfo, at *Williamfburg*,

O   in

in *Virginia*, latitude 37° 20´ N. the annual range is above 1 inch, which is the fame as at *Genoa*, latitude 44° 25´ N.

6. In the temperate zones the mean ftate of the barometer in the fummer months is nearly equidiftant from the extremes in that feafon; but in winter the mean is much nearer the higher extreme than the lower.

According to the obfervations at *Kendal* (fee page 16*) the mean height of the barometer in July is diftant from the higher extreme .33 of an inch, and from the lower extreme .37; in January the mean is diftant from the higher extreme .79, and from the lower 1.17: the ratio of the former diftances is as 11 to 12, and of the latter as 8 to 12, nearly.

Profeffor *Muffchenbroek*, in his Elements of Natural Philofophy, (tranflated by *Colfon*) publifhed about 50 years ago, has endeavoured to account for thofe changes of weight in the atmofphere; he has adverted to all or moft of the caufes that have ever been confidered as agents in producing the effects: he enumerates the following caufes, namely;—Firft, the oppofition of winds; fecond, the north wind blowing, which cools and condenfes the air; third, the winds blowing upward or downward; fourth, an increafe or diminution of heat, which rarefies or condenfes the air, in confequence of which the air's diftance from the earth's centre is increafed or diminifhed, and its weight, as well as centrifugal force, thereby affected; fifth, the air
being

* The mean for July, uncorrected, is 20.77, and for January 29.66, which muft be ufed in this cafe, becaufe the extremes are not corrected.

being loaded with, or cleared of vapours and exhalations.

Profeſſor *De Sauſſure*, of *Geneva*, thinks the cauſes of the changes of the barometer are heat, different winds, and unequal denſity of the contiguous *ſtrata* of air; hence the little variation within the tropics. The principal cauſe is oppoſing winds. He does not deny that chymical changes in the air may affect the barometer; he however ſuſpects that ſome unknown cauſe has the greateſt effect *.———We ſhall now conſider the cauſes above alleged ſeverally.

The idea of oppoſite winds having the principal ſhare in producing the changes in the barometer, has evidently been ſuggeſted by the uniformity of the trade-winds, and the ſmall variation of the barometer where they blow; but it ſhould be conſidered, that the land-winds within the tropics do not always blow with the general or trade-winds, and that ſometimes they are in direct oppoſition; alſo, the monſoons, eſpecially about their change, produce uncommon conflicts of winds, and tempeſtuous weather, notwithſtanding which circumſtances, the barometer never has thoſe fluctuations that are experienced in the other zones. If, therefore,

O 2   the

* Theſe his ſentiments are taken from the *Critical Reviews,* for 1787.—Without being poſſeſſed of his work, we cannot examine his arguments particularly.

the idea of oppofite winds, mechanically accumulating or diſperſing the air, be inconfiſtent with the firſt fact, it will certainly fail of explaining the reſt. Befides, it would not be difficult to prove, *a priori*, that the oppoſition of winds, admitting the fact at the time, could not produce thoſe great and long continued accumulations of air which we often experience.

The fecond caufe, or that of a cold north wind blowing, has doubtleſs an effect upon the barometer, though perhaps not altogether in the manner that has been conceived.—We ſhall confider this in another point of view by and by.

The third caufe, fuppofing it to exiſt at any time, can only be local and tranfitory at moſt; but the rife or fall of the barometer is general, and of confiderable duration: it cannot, therefore, produce the effect.

The fourth caufe is much too trifling to have any material influence.

With refpect to the fifth, it muſt be allowed, that water, when changed into vapour, confitutes a part of the atmofphere for the time, and weighs with it accordingly; alfo, that when vapour is precipitated in form of rain, the atmofphere lofes the weight of it: but it would be too haſty to conclude from hence, that where evaporation is going forward the barometer muſt rife, and where rain is falling it muſt fall alfo; becaufe air loaden with vapour is found to be fpecifically lighter than without it. Evaporation, therefore,

increaſes

increafes the bulk and weight of the atmofphere at large, though it will not increafe the weight over any particular country, if it difplace an equal bulk of air fpecifically heavier than the vapour: and in like manner, rain at any place may not diminifh the weight of the air there, becaufe the place of the vapour may be occupied by a portion of air fpecifically heavier. It fhould feem therefore, that when the air over any country is cleared of vapours, &c. the barometer ought to be higher than ufual, and not lower.——But we fhall now proceed to ftate our own ideas on the fubject.

It appears from the obfervations, (fee table, page 16) that the mean ftate of the barometer is rather lower than higher in winter than in fummer, though a ftratum of air on the earth's furface always weighs more in the former feafon than in the latter; from which facts we muft unavoidably infer, that the height of the atmofphere, or at leaft of the grofs parts of it, is lefs in winter than in fummer, conformable to the table, page 83. There are more reafons than one to conclude that the annual variation in the height of the atmofphere, over the temperate and frigid zones, is gradual, and depends in a great meafure upon the mean temperature at the earth's furface below; for, clouds are never obferved to be above 4 or 5 miles high, on which account the clear air above can receive
little

little or no heat, but from the fubjacent regions of the atmofphere, which we know are influenced by the mean temperature at the earth's furface; alfo, in this refpect, the change of temperature in the upper parts of the atmofphere muft, in fome degree, be conformable to that of the earth below, which we find by experience increafes and decreafes gradually each year, at any moderate depth, according to the temperature of the feafon. (See page 30.)

Now with refpect to the fluctuations of the barometer, which are fometimes very great in 24 hours, and often from one extreme to the other in a week or 10 days, it muft be concluded, either that the height of the atmofphere over any country varies according to the barometer, or otherwife that the height is little affected therewith, and that the whole or greateft part of the variation is occafioned by a change in the denfity of the lower regions of the air. It is very improbable that the height of the atmofphere fhould be fubject to fuch fluctuations, or that it fhould be regulated in any other manner than by the weekly or monthly mean temperature of the lower regions; becaufe the mean weight of the air is fo nearly the fame in all the feafons of the year, which could not be if the atmofphere was as high and denfe above the fummits of the mountains in winter as it is in fummer. However, the decifion of this queftion

need

need not reft upon probability; there are facts, which sufficiently prove, that the fluctuation of denfity in the lower regions has the chief effect upon the barometer, and that the higher regions are not subject to proportionable mutations in denfity. In the memoirs of the Royal Academy at *Paris*, for 1709, there is a comparifon of ob-fervations upon the barometer at different places, and amongft others, at *Zurick*, in *Switzerland*, in latitude 47° N. and at *Marfeilles*, in *France*, latitude 43° 15′ N.; the former place is more than 400 yards above the level of the fea; it was found that the annual range of the baro-meter was the fame at each place, namely, about 10 lines; whilft at *Genoa*, in latitude 44° 25′ N. the annual range was 12 lines, or 1 inch; and at *Paris*, latitude 48° 50′ N. it was about 1 inch 4 lines. In the fame memoir it is related, that F. *Laval* made obfervations, for 10 days toge-ther, upon the top of *St. Pilon*, a mountain near *Marfeilles*, which was 960 yards high, and found that when the barometer varied 2¼ lines at *Mar-feilles*, it varied but 1¼ upon *St. Pilon*. Now had it been a law, that the whole atmofphere rifes and falls with the barometer, the fluctua-tions in any elevated barometer would be to thofe of another barometer below it, nearly as the abfolute heights of the mercurial columns in each, which in thefe inftances were far from being fo. Hence then it may be inferred, that the fluctuations of the barometer are occafioned

chiefly

chiefly by a variation in the denſity of the lower
regions of the air, and not by an alternate ele-
vation and depreſſion of the whole ſuperincum-
bent atmoſphere.   How we conceive this fluctu-
ation in the denſity of the air to be effected, and
in what manner the preceding general facts re-
lative to the variation of the barometer may be
accounted for, is what we ſhall now attempt to
explain.

It has been obſerved already that air charged
with vapour, or vapourized air, is ſpecifically
lighter than when without the vapour; or, in
other words, the more vapour any given quan-
tity of atmoſpheric air has in it, the leſs is its
ſpecific gravity.—M. *De Sauſſure* has found from
experiment, that a cubic foot of dry air, of a
certain temperature, will imbibe 12 grains of
water; and that every grain of water diſſolved
in air becomes an elaſtic fluid capable of ſup-
porting $\frac{1}{24}$ of an inch of mercury, while its den-
ſity to that of air, is as 3 to 4.—Again, Dr.
Prieſtley has found from frequent experiments
(vid. *Experiments and Obſervations relating to va-
rious branches of natural Philoſophy,* Vol. 6, page
390) that different kinds of air, as for inſtance,
inflammable air, and dephlogiſticated air, the
ſpecific gravities of which are as 1 to 12 nearly,
when mixed together, do not obſerve the laws
of hydroſtatics ; for, the inflammable air, inſtead
of riſing to the top of the veſſel, diffuſes itſelf
equally

equally and permanently through the dephlogisticated air, at the same time that no chemical attraction takes place betwixt them. The Doctor further observes, " that the phlogisticated " and dephlogisticated air, which compose the " atmosphere, are of very different natures, " though without any known principle of attraction between them, and also of different " specific gravities ; and yet they are never separated but by the chemical attraction of substances, which unite with the one and leave " the other."—Moreover, Sir *Benjamin Thompson* has found that moist air conducts heat better than dry air. *(Vid.* Philosophical Transactions, 1786.)

From the two first mentioned discoveries we may venture to infer, that if a cubic foot of dry air were mixed with a cubic foot of moist air of the same temperature, the compound would occupy a space of two cubic feet, and be of equal elasticity with the simples, the two kinds of air being intimately diffused through each other. Hence then a fluctuation of the density of the air may happen thus : if a current of warm and vapourized air flow into a body of cold and dry air, it will displace a part of the cold air, and diffuse itself amongst the rest, by which means the weight of the *stratum* will be diminished, whilst its bulk and spring remain the same ; and *vice versa,* if dry air flow into vapourized air.

P The

The firſt fact may then be accounted for thus:
—the warmer any air is, the more water it will
imbibe, in ſimilar circumſtances; hence, the air
over the torrid zone, being the hotteſt, will
contain the moſt vapour; and the air about the
poles, being the coldeſt, will contain the leaſt * :
moreover, as the heat within the torrid zone,
and the height of the atmoſphere there, remain
pretty nearly the ſame all the year round, and
all the air approaching the zone from the two
temperate zones, is gradually aſſimilated in its
paſſage to that of the ſaid zone, it follows, that
there can be little fluctuation of denſity in the
lower regions of the air, and of courſe little va-
riation of the barometer in the torrid zone.

The ſecond and third facts are the neceſſary
reſults of the principles we are aſſerting:—in
winter, the ſeaſon when the barometrical range
is obſerved to be greateſt, the temperature of
the air decreaſes in proceeding from the torrid,
through the temperate, to the frigid zones; the
decreaſe

---

* The reader will pleaſe to obſerve, that the terms *moiſt
air*, and *vapourized air*, uſed in this and ſome other eſſays,
denote air containing a great portion of vapour, though it
may not perhaps be characterized as ſuch by a hygrometer.
—Thus, a cubic foot of air at the equator, which there is
indicated to be dry by a hygrometer, will contain more va-
pour than a cubic foot of air here, at the freezing tempera-
ture, which is indicated to be more moiſt than the former
by the hygrometer.—The difference of temperature pro-
duces this effect.

decreafe is at firſt moderate, but grows more and more rapid as we advance; in confequence of this decreaſe, and the law by which it is regulated, every place in the temperate zone will, then more particularly, be fituate betwixt the extremes of heat and cold, relative to its own temperature, and the higher the latitude the nearer will be thofe extremes to the place; befides, that feaſon being liable to the higheſt winds, the air will readily be transferred from one parallel to another; and as the air at all times will endeavour to maintain a proportion of vapour fuitable to its temperature, it follows, that the air in general in the higher latitudes will then both be *cold* and *dry.* and in the lower latitudes both *warm* and *moiſt*, relatively fpeaking. The confequence is obvious, that as a current from one or the other hand prevails, the barometer will rife or fall accordingly, and the rife or fall will be greater as the place is fituate nearer to the extremes of temperature, becaufe the air will in that cafe fuffer the leaft change in its paffage.———In ſummer, the heat all over the northern hemiſphere is brought almoſt to an equality at the different parallels; the whole maſs of air is heated, fwelled, and replenifhed with vapour; the air over the northern regions is almoſt brought into the fame ſtate as within the tropics, and the barometer therefore has almoſt as little variation, in that feafon, here as there.

The

The fourth fact offers nothing inconfiftent with our theory : winds are the mediate caufe of the variations of the barometer, and the currents of air to and from the torrid zone are not partial, but general, though fubject to confiderable modifications in direction ; befides, independent of winds, thofe properties of the air, heat and moifture, will always be diffufing themfelves in every direction, where there is a deficiency of either ; from which circumftances, it feems impoffible that the variations of the barometer fhould be local, though the amount of each fluctuation will not be the fame at places confiderably diftant. From the ufual celerity of the winds, the changes will happen upon the fame day at places very diftant ; but theory feems to require, that the northern parallels fhould firft experience the higher extremes, and the fouthern parallels the lower, and the obfervations upon the fourth fact countenance the inference. However, a feries of cotemporary obfervations made at two places, differing confiderably in latitude, would afcertain the fact ; and if the places were one NE. of the other, they would be ftill more eligible for the purpofe, becaufe the two general currents of air flow in that direction.

The climate of the eaftern coaft of *North America* is fo conftituted, that the decreafe of the mean temperature in the winter feafon, in proceeding northward, is much more rapid than

on the weſtern coaſt of this continent; the conſequence is, that any particular place there is liable to great and ſudden fluctuations of temperature in that ſeaſon, and theſe produce proportionate fluctuations of the barometer, according as the warm and vapoury, or the cold and dry air predominate.

The ſixth fact has not, that I know of, ever been accounted for, or even been adverted to, by thoſe who have attempted to explain the cauſes of the variation of the barometer; and yet it will admit of a ſatisfactory explanation upon the principles we have adopted. Indeed, at firſt view, it ſeems inconſiſtent with thoſe principles, becauſe we can produce no facts to prove why the air may not deviate from its mean ſtate of heat and moiſture as much towards one extreme as towards the other; but, allowing what is moſt probably the true ſtate of the caſe, that the deviations on each ſide are nearly equal, ſtill the fact of the barometer admits of a rational ſolution.—Moiſt air, as has been obſerved, conducts heat much better than dry air; now when the loweſt extreme of the barometer happens, the air is moiſt, high winds generally prevail, and the atmoſphere is much ruffled by clouds and ſtorms; all theſe circumſtances tend to diffuſe and circulate the heat, by reaſon of which the law of decreaſe of temperature in aſcending, at ſuch times, muſt be very

materially

materially different from what it is in ferene
weather; or, in other words, the decrease of
temperature in ascending must be much slower
than at other times; we may venture to suppose,
that, in some cases, the mean state of decrease
for a few miles of elevation will be 1° for every
150 yards of ascent, instead of 1° for every 100
yards, which is the usual rate; the consequence
of this must be a greater reduction of the baro-
meter than otherwise would happen.   For, let
the weight of the atmosphere at 3 miles of eleva-
tion be supposed equal to 15 inches of mercury,
the heat at the earth's surface equal to 45°, and
that it decreases in ascending after the usual rate
of 1° for every 100 yards; then, the mean heat
of a column of air from the earth's surface to 3
miles above it, will be 18°.6, whence the weight
of the whole column from the earth's surface to
the top of the atmosphere may be found by the
theorem, page 82; or $H = \dfrac{600b + p}{600b - p} \times y$ (y be-
ing given in this case) = 8.74 inches, the height
of the mercurial column of the barometer at the
earth's surface: but if we suppose the heat de-
creases in ascending after the rate of 1° for 150
yards, then the mean heat of the column be-
comes equal to 27°.4, and the height of the
barometer equal to 28.30 inches; the difference
is .44 of an inch, occasioned by this change in
the temperature, which is greater by .06 of an
inch than the difference of the ranges above

and

and below the mean for January, at *Kendal,* as ſtated at page 98.

The ſuppoſition made above, I preſume will not be deemed extravagant, namely, that the mean heat of a column of air 3 miles high will not differ more from that at the earth's ſurface than 17°, on certain occaſions: when we conſider the ſtrong SW. winds during a thaw, (when the loweſt extreme uſually happens) and that the thermometer often riſes to 45° at the ſame time that the froſt is in the earth, and the ground not cleared of ſnow, we muſt conclude, that the then increaſing heat comes from the air above, and not from the earth, and conſequently that the temperature of the air is greateſt at a conſiderable elevation, and decreaſes from thence downward as well as upward; which circumſtance alone will greatly add to what the mean temperature of the column would otherwiſe be. —This irregularity and inverſion of the law of heat in the atmoſphere, by which the loweſt extreme of the barometer is removed farther from the mean ſtate than the higheſt, can only happen in winter, by means of a ſudden influx of warm air into cold; but in ſummer the heat of the air, being chiefly derived from the earth's ſurface, will be more equably diffuſed upwards, and prevent ſuch a diſproportion in the diſtances of the extremes from the mean, agreeably to obſervation.

Having

Having now endeavoured to explain the principal facts relative to the variation of the barometer, we shall next advert to some other particulars on the subject, which tend to illustrate and confirm the doctrine we have advanced.

The barometer generally rises with a wind betwixt the north and the east; it rises very high during a long and uninterrupted frost; it was highest for the last 5 years in January 1789; the mean temperature at *Kendal*, for 4 weeks preceding, was 28°, which was lower than for any other similar interval in the 5 years; there was only 1.643 inches of rain and snow for 7 weeks before; these were clear proofs of the prevalence both of cold and dry air.

The barometer is often low in winter, when a strong and warm S. or SW. wind blows; the annual extremes for these 5 years have always been in January; the lowest was in January, 1789, about 2 weeks after the above mentioned high extreme; it was accompanied with a strong S. or SW. wind, and heavy rain; the temperature of the air at the time was not high, being about 37°, but the reason was no doubt because one half of the ground was covered with snow; it was therefore probably warmer above.—Now the reason why the low extreme should have at that time, as well as at many others, soon succeeded the high extreme, seems explicable as

follows :

follows: the extreme and long continued cold preceding, muſt have reduced the groſs part of the atmoſphere unuſually low, and condenſed an extraordinary quantity of dry air into the lower regions; this air was ſucceeded by a warm and vapoury current coming from the torrid zone, before the higher regions, the mutations of which in temperature and denſity are ſlow, had time to acquire the heat, quantity of matter, and elevation conſequent to ſuch a change below; theſe two circumſtances meeting, namely, a low atmoſphere, and the greateſt part of it conſtituted of light, vapoury air, occaſioned the preſſure upon the earth's ſurface to be ſo much reduced. Hence then, it ſhould ſeem, we ought never to expect an extraordinary fall of the barometer, unleſs when an extraordinary riſe has preceded, or at leaſt a long and ſevere froſt; this, I think, is a fair induction from the foregoing principles; how far it is corroborated by paſt obſervations, beſides thoſe juſt mentioned, I have not been able to learn.

It is obſervable that the high extreme ſome years happens in October or March, but generally in one of the intermediate months; the low extreme is moſtly in December or January. From the obſervations at *Paris* for 20 years, from 1699 to 1718, incluſive, if we take 11 of the loweſt that were made, 10 of them were in December and January, and the eleventh in November.

The

The month of January, 1791, will be long remembered, on account of the losses at sea, and damage at land, by the extraordinary high winds, which prevailed almost inceffantly throughout the month, from the SW.—See page 49   Now a ftrong and warm SW. wind blowing continually in that feafon, when the atmofphere was low, ought to have reduced the mean ftate of the barometer unufually low; the fact therefore may be produced, as an *experimentum crucis* of the theory; accordingly, we find from the obfervations, that the mean ftate of the barometer for that month was lower by .14 of an inch, in the north of *England*, and probably lower every where on the weftern coaft of *Europe*, than for any other month in the laft 5 years.

It does not appear from the barometrical obfervations in the firft part of this book, that cold alone, independent of every other circumftance, has a tendency to increafe the mean weight of the atmofphere over any place; for, if it had, the mean ftate of the barometer would be higher in winter than in fummer, contrary to experience; if, therefore, the mean ftate of the barometer be lower in the torrid than frigid zones, it is moft probably effected by the vapoury air.

ESSAY

ESSAY FOURTH.

On the relation between Heat and other Bodies.

WE have nothing new to offer on this fubject; but as fome knowledge of the matter is requifite in order to underftand fome of the phenomena of meteorology, we purpofe to give a brief explanation of fuch facts as may be adverted to in the courfe of this work.

Different bodies that are equal in *magnitude,* and of the fame temperature, do not contain equal quantities of fire; neither do different bodies, that are equal in *weight* and temperature, contain equal quantities of fire.—For example, if a cubic inch of *iron* be heated to 100°, and then thrown into a given quantity of water at 50°, the temperature of the water will be augmented; but if inftead of *iron,* lead be ufed, the temperature will not be fo much augmented; on the contrary, if the iron and lead were colder than the water, the iron would diminifh its temperature moft. If equal *weights* of iron and lead were ufed, the refults would be fomewhat different, but ftill the temperature of the water would be more augmented or diminifhed by the iron than by the lead. When equal *weights* are ufed in experiments of this fort, that body which augments or diminifhes the temperature the moft, is faid to have the greater capacity for heat; be-

Q 2   caufe

ESSAY FIFTH.

On the Temperature of different Climates and Seasons.

MR. *Kirwan* has treated of this subject in so able a manner, that we can do little more than extract from his work *.

That the sun is the primary cause of heat all over the earth, is almost too apparent ever to have admitted of doubt; though some philosophers have imagined a *central heat* or body of fire in the earth, which, by its emanations, mitigates the severity of the winters in the higher latitudes: the opinion is, however, disproved by facts, which shew, that the temperature of places 30, 40, or 50 feet below the earth's surface, remains nearly the same all the year round as the mean annual temperature at the surface, and that at a less depth the temperature varies, in a small degree, with the season. The fact seems to be, that in winter the earth gives out to the atmosphere a portion of heat received in summer.

The earth's surface is the chief medium by which the sun heats the atmosphere; for it is
obfervable

* *Estimate of the Temperature of different Latitudes.*

denfed into water of the fame temperature, gives out 943° of heat.

The capacities of *earth*, *ftones*, and *fand*, for heat, are much lefs than that of water. This is one caufe why the viciffitudes of temperature are greater at land than at fea*.

Another particular relative to heat is, that fome bodies conduct it better than others; in this refpect there is a ftriking refemblance between the electric fluid and fire; for, thofe bodies which conduct the electric fluid well, as metals, water, &c. alfo conducts heat well.——*Glafs*, *fealing-wax*, and other electrics, conduct heat very flowly; alfo *dry land*, whether the furface be ftony, fandy, or earthy, is found by experience to conduct heat flowly.

Sir *B. Thomfon* has by a feries of experiments (fee Philofophical Tranfactions, 1786) found the powers of a few bodies to conduct heat to be proportionate to the following numbers, namely:

Mercury - - - - - - - - -	1000
Moift air - - - - - - - -	330
Water - - - - - - - -	313
Common air, denfity 1 - - - -	80.11
Rarefied air, denfity ¼ - - -	80.23
Rarefied air, denfity 1/24 - - -	78
Torricellian vacuum - - - -	55

ESSAY

* Thofe who wifh to fee the fubject touched upon above, difcuffed at large, may perufe Dr. *Crawford's Experiments and Obfervations on Animal Heat and the Inflammation of combuftible Bodies.*

120 On the Temperature of Climates, &c.

Mr. *Kirwan*, confidering thefe and other cir-
cumftances, judges it moft eligible, in comparing
the temperature of different places, to fix upon a
fituation that may ferve as a ftandard of compa-
rifon, and he judicioufly prefers the fea to the
land, as being more free from accidental vari-
ations. By combining theory with obfervation,
he obtains the mean annual heat of the equator
equal to 84°, and that of the pole 31°; and then
gives the following theorem for the mean annual
temperature of the ftandard fituation in every
latitude; namely, if $S =$ the natural fine of any
latitude to radius 1; then, $84 - 53 \times S =$ the
mean annual temperature of that latitude.

This theorem gives the temperature of dif-
ferent latitudes as by the following table.

*Table of the mean annual temperature of the ftandard
fituation, for every 5 degrees of latitude.*

Lat.	temp.	Lat.	temp.	Lat.	temp.	Lat.	temp.	Lat.	temp.
°	°	°	°	°	°	°	°	°	°
0	84	20	77.8	40	62	60	44.3	80	32.6
5	83.6	25	74	45	57.5	65	40.5	85	3_.4
10	82.3	30	70.7	50	52.9	70	3_.2	90	31
15	80.4	35	66.6	55	48.4	75	34.6		

It afterwards becomes neceffary to confider
the modifications of the ftandard temperature
on land; from fituation, &c.

1. Elevation diminifhes the mean temperature
of places. Its effects Mr. *Kirwan* ftates as fol-
lows:

lows: if the elevation be moderate, or at the rate of 6 feet per mile from the nearest sea; then, for every 200 feet of elevation, allow ¼ of a degree for the diminution of the mean annual temperature.

If the elevation be 7 feet per mile, allow ⅓ of a degree.
$\qquad$ 13 feet $\qquad$ $\frac{4}{10}$
$\qquad$ 15 feet, or upwards $\qquad$ ½

N. B. The elevation of any inland place may be found sufficiently exact for this purpose, by observing how much the mean annual height of the barometer falls short of 30 inches, and allowing for the difference, according to the theorem in page 81; because the mean annual height of the barometer, on a level with the sea, is nearly 30 inches every where.

2. Next to elevation, distance from the standard ocean seems to have the most considerable effect upon the mean annual temperature; its amount Mr. *Kirwan* states, from a comparison of observations, as follows: namely, the mean annual temperature is depressed or raised, for every 50 miles distance, nearly at the following rate:

From lat. 70° to lat. 35° *cooled* ⅔ of a degree.
$\qquad$ 35 to 30 $\qquad$ ⅛
$\qquad$ 30 to 25 *warmed* ⅓
$\qquad$ 25 to 20 $\qquad$ ½
$\qquad$ 20 to 10 $\qquad$ 1°.

This

This effect of distance from the standard o-
cean Mr. *Kirwan* seems to attribute to the un-
equal capacities of land and water for heat; but,
with deference to the opinion of so respectable a
philosopher, I think this alone inadequate to the
effect.   For, if land in general receive *more* heat
immediately from the sun in a year than water,
the mean temperature of the internal parts of
the continent ought to be the greatest from the
equator to the pole.   And if land receive *less*
heat, then, for ought that appears, the mean
temperature of the internal parts of the conti-
nent might be expected the least in every lati-
tude; but in neither case, I think, could we
conclude *a priori,* from the mere difference of
capacity, that the mean heat of the internal parts
of the continent would be greater near the equa-
tor, and less more northward, than the mean
heat upon the coast.—To account for the effect
in question, we shall therefore propose the fol-
lowing theory.

Let it be first supposed that water receives a
greater quantity of heat, from the sun's rays,
than land in general, under every parallel of la-
titude *; in the next place, it will be allowed,
that a much greater quantity of water is evapo-
rated

* It is generally allowed, I think, that land reflects more
light than water, and consequently imbibes less; and the
quantity of heat received will doubtless be proportionate to
the rays imbibed.

rated from the fea, in the torrid zone, than from
an equal area of land in the fame zone; hence
it will follow, that the quantity of heat abforbed
by the vapour may, for ought we know, be fo
great as to reduce the mean temperature of the
fea there below that of the land: in fuch cafe it
is evident, the further any place is diftant from
the fea, the greater muft its mean temperature
' be, all other circumftances being the fame. A-
gain, the farther we proceed northward, the lefs
is the quantity of water annually evaporated
from a given furface of the fea; hence there
may be a parallel of latitude where the heat ab-
forbed by the greater evaporation of the fea, is
equal to the heat which the fea receives more
than the land; in this cafe therefore, the mean
temperature of the land and fea will be every
where the fame in the fame parallel. Farther
than this, the mean temperature of the fea will
become greater than that of the land, and the
more fo as the latitude increafes. It appears
then, that the difference of the capacity of land
and water for heat, requires to be joined to the
fuppofition that water receives more abfolute
heat than land from the fun's rays, before we
can produce, *a priori*, a refult fimilar to what is
ftated above as deduced from obfervation.

But if we purfue the thought ftill farther, we
fhall perhaps find, that the above ftatement of
the effect of diftance from the ftandard ocean,

is

is not altogether compatible either with theory or obfervation,—and at the fame time draw a conclufion of much importance to the fubject we are now difcuffing.

It is obfervable, that in the northern tempe-rate zone, the internal parts of the eaftern con-tinent are generally hotter, in fummer, than on the coaft under the fame parallel, except eleva-tion or fome peculiarity of foil or fituation dimi-nifh the temperature; but the cold of winter is fo much more fevere, that the mean temperature is greatly reduced below the ftandard — Now in winter, when the influence of the fun is fo weak, it fhould feem that the condenfation of vapour alone affords the northern atmofphere a very large portion of the fenfible heat it has in that feafon. And it appears in the former effay on winds, that the general current of air from the equator is SW. when it arrives in the northern temperate zone; this current coming from the fea to the weftern coaft of each continent, will there meet with cold air, which condenfes its vapour as it proceeds, affording plenteous rain and heat to the weftern coafts : as the current proceeds into the internal parts of the continents it lofes its vapour and heat, till at length the precipitation becomes much lefs in quantity, and in form of fnow; the current then continues its progrefs, and grows colder and colder till it ar-rives at the eaftern coaft, unlefs the influx of fea
breezes

breezes mitigate the temperature near the coaſt. Hence then it may be inferred, *that in the temperate zones, the weſtern coaſts of all continents and large iſlands, will have a higher mean temperature than the eaſtern coaſts under the ſame parallel, and particularly will have more moderate winters.*

It remains now to ſhew how far this inference is countenanced by obſervation.—We are certain that the eaſtern coaſt of *Aſia* is much colder than the weſtern coaſt of *Europe*; on the eaſtern coaſt of *Kamſchatka*, in latitude 55° N. Capt. *Cook* found ſnow 6 or 8 feet deep, in May, and the thermometer was moſtly 32°; and in January the cold is ſometimes — 28°, and generally —8°. At *Pekin*, in *China*, latitude 39° 54′ N. longitude 116° 29′ E. the mean temperature is only 55°.5, the *Atlantic* under this parallel being 62°; the uſual range of the thermometer each year is from 5° to 98°, not unlike what it is at *Philadelphia*, which is under the ſame parallel. —Again, we are certain that the eaſtern coaſt of *North America* is 10 or 12° colder than the oppoſite weſtern coaſt of *Europe*; and hence it may be preſumed, that the weſtern coaſt of *North America*, or that of *California*, is warmer than the eaſtern. The N.E. parts of *Siberia* on the one continent, and the country about *Hudſon's Bay* on the N.E. ſide of the other continent, ſeem equally ſubject to the moſt rigorous cold

in

in winter.———But to proceed to the other mo-
difications of the standard temperature.

3. As for the effects of mountains, forests,
seas, &c. upon the mean annual temperature of
places, Mr. *Kirwan* observes, that all countries
lying to the windward of high mountains, and
extensive forests, are warmer than those lying to
the leeward, in the same latitude. Countries
that lie southward of any sea are warmer than
those that have that sea to the south of them.
Islands participate most of the temperature of
the sea, and are therefore not subject to the ex-
tremes of heat and cold so much as continents.

We shall here introduce a table containing
the mean annual temperature of several places,
as determined by observation, from the " Esti-
mate, &c." page 113.

	North Lat.	Longitude.	Mean annual Heat.
Wadso, in Lapland - -	70° 5		36°
Abo - - - -	60 27	22°18 E.	40
Petersburgh - - -	59 56	30 24 E.	38 8
Upsal - - - -	59 51	17 47 E	41.88
Stockholm - - -	59 20	18 E.	42.39
Solyskamski - - -	59	54 E.	36 2
Edinburgh - - -	55 57	3 W	47.7
{ Keswick * - - -	54 33	3 3 W	46
{ Kendal - - - -	54 17	2 46 W.	46.4

Franeker

* These two places are inserted from page 29 and 30 of this work.

	North Lat.	Longitude	Mean annual Heat.
Franeker - - -	53° 0	5° 42' E.	52°.6
Berlin - - -	52 32	13 31 E.	49
Lyndon, in Rutland -	52 30	0 3 W.	48.03
Leyden - - -	52 10	4 32 E.	52 25
London - - -	51 31		51.9
Dunkirk - - -	51 2	2 7 E.	54 9
Manheim - - -	49 27	9 2 E.	51.5
Rouen - - -	49 26	1 W.	51
Ratisbon - - -	48 56	12 5 E.	49.35
Paris - - -	48 50	2 25 E.	52
Troyes, in Champaigne -	48 18	4 10 E.	53.17
Vienna - - -	48 12	16 22 E.	51.53
Dijon - - -	47 19	4 57 E.	52.8
Nantes - - -	47 13	1 28 E.	55.53
Poitieres - - -	46 39	0 30 E.	53.8
Lausanne - - -	46 31	6 50 E.	48.87
Padua - - -	45 23	12 E.	52.2
Rhodes, in Guienne -	45 21	2 39 E.	52 9
Bordeaux - - -	44 50	0 36 W.	57.6
Montpelier - - -	43 36	3 73 E.	60 87
Marseilles - - -	43 19	5 27 E.	61.8
Mont Louis, in Roussillon -	42	2 40 E.	44.5
Cambridge, in New England	42 25	71 W.	50.3
Philadelphia - -	39 56	75 9 W.	52.5
Pekin - - -	39 54	116 29 E.	55.5
Algiers - - -	36 49	2 17 E.	72
Grand Cairo - -	30	31 23 E.	73
Canton - - -	23	113 E.	75.14
Tivoli, in St. Domingo -	19		74
Spanish Town, in Jamaica -	18 15	76 38 W.	81
Manilla - - -	14 36	120 58 E.	78.4
Fort St. George - -	13	87 E.	81.3
Ponticherry - -	12	67 E.	88
	South Lat.		
Falkland Islands - -	51° 0'	66 W.	47.4
Quito - - -	0 13	77 50 W.	62

The hottest place mentioned in this table is *Pontcherry;* the heat there is sometimes 113 or 115°, which far exceeds that of the human body. The mean heat of June is 95°.4.

In some parts of *Africa* the heat even exceeds that of *Ponticherry*.

Of all inhabited countries, *Siberia* seems the coldest; its great elevation and distance from the ocean both conspire to make it so. Mercury has often been frozen there by the natural cold, which consequently exceeded —39°. The mean temperature of *Irkutz*, latitude 52° 15´ N. longitude 105° E. from October 1780 to April 1781, was —6°.8.

At *Petersburgh* the cold has been known —39°: and is one year with another, at an average, —25°; the greatest summer heat, on a mean, is 79°, yet once it amounted to 94°.

General Observations and Inferences.

Estimate, &c. page 19. " The temperatures of different years differ very little near the equator, but they differ more and more, as the latitudes approach the poles.

" It scarce ever freezes in latitudes under 35°, unless in very elevated situations; and it scarce ever hails in latitutes higher than 60°.

" Between latitudes 35° and 60°, in places adjacent to the sea, it generally thaws when the sun's altitude is 40°, and seldom begins to freeze until the sun's meridian altitude is below 40°."

Page 28. " The greatest cold, within the 24 hours, generally happens half an hour before sun-rise, in all latitudes. The greatest heat in all

all latitudes between 60° and 45°, is found about half paſt 2 o'clock in the afternoon; between lat. 45° and 35°, at 2 o'clock; between lat. 35° and 25°, at half paſt 1; and between lat. 25° and the equator, at 1 o'clock.

" On ſea, the difference between the heat of day and night, is not ſo great as on land, particularly in low latitudes.

" The coldeſt weather, in all climates, generally prevails about the middle of January, and the warmeſt in July, though, aſtronomicaily ſpeaking, the greateſt cold ſhould be felt at the latter end of December, and the greateſt heat in the latter end of June; but the earth requires ſome time to take, or to loſe the influence of the ſun, in the ſame manner as the ſea, with reſpect to tides, does that of the moon."

Page 104, &c. " July is the warmeſt month in all latitudes above 48°; but in lower latitudes Auguſt is generally the warmeſt.

" December and January, and alſo June and July, differ but little. In latitudes above 30°, the months of Auguſt, September, October, and November, differ more from each other, than thoſe of February, March, April, and May. In latitudes under 30°, the difference is not ſo great. The temperature of April approaches

S   more,

more, every where, to the annual temperature, than that of any other month: whence we may infer, that the effects of natural caufes, that operate gradually over a large extent, do not arrive at their *maximum*, until the activity of the caufes begins to diminifh; this appears alfo in the operation of the moon on feas, which produces tides; but after thefe effects have arrived at their *maximum*, the decrements are more rapid, than the increments originally were, during the progrefs to that *maximum**.

" The differences between the hotteft and coldeft months, within 20° of the equator, are inconfiderable, except in fome peculiar fituations; but they increafe in proportion, as we recede from the equator.

In

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* The foregoing obfervations, made at *Kendal* and *Kefwick*, afford fome remarkable exceptions to the three laft general obfervations.——December is the coldeft month in thefe places; though perhaps a mean of 5 years is not fufficient to détermine the point. Auguft is generally the warmeft month, and not July; the reafon of this laft I take to be, our mountains being topped with fnow during the fpring, which retards the increafe of temperature, and throws the *maximum* of heat later in the fummer. For the fame reafon, the month of April is colder than the annual mean: October feems the neareft to it. The ftandard temperature for thofe places is 49°; the difference, being between 2 and 3°, muft be attributed, I think, chiefly to the extenfive ranges of mountains and high lands, in almoft every direction; unlefs, perhaps, we have determined the temperature too low.——See the obfervations, page 30.

In the higheſt latitudes, we often meet with a heat of 75 or 80°; and particularly in latitudes 59° and 60°, the heat of July is frequently greater than in latitude 51°.

Every habitable latitude enjoys a heat of 60° at leaſt, for 2 months; which heat ſeems neceſſary, for the growth and maturity of corn. The quickneſs of vegetation, in the higher latitudes, proceeds from the duration of the ſun over the horizon. Rain is little wanted, as the earth is ſufficiently moiſtened by the liquefaction of the ſnow, that covers it during the winter; in all this, we cannot ſufficiently admire the wiſe diſpoſition of Providence.

ESSAY

ESSAY SIXTH.

On Evaporation, Rain, Hail, Snow, and Dew.

EVAPORATION is that procefs in nature
by which water and other liquids are ab-
forbed into the atmofphere, or are converted
into elaftic fluids, and diffufed through the at-
mofphere; the liquid thus changed, is termed
vapour, and the vapour is characterized by the
name of the liquid from which it was generated,
as *aqueous vapour*, or the vapour derived from
water, &c.—Whether the vapour of water is
ever chymically combined with all or any of the
elaftic fluids conftituting the atmofphere, or it
always exifts therein as a fluid *fui generis*, dif-
fufed amongft the reft, has not, I believe, been
clearly afcertained.

The following circumftances are found pow-
erfully to promote evaporation; namely, *heat*,
dry air, and a *decreafed weight* or *preffure* of the
atmofphere upon the evaporating furface. The
firft and fecond are known to have that effect,
from every one's experience; the laft is proved
to have fuch an effect, by the air-pump. For,
when the air is exhaufted out of a receiver, a
large quantity of vapour is raifed from the wet
leather upon the pump plate; this vapour is
precipitated again when the air is let in, fo as to
appear

appear falling like a shower*. If a quantity of
warm water be placed under a receiver, when
the air is rarefied to a sufficient degree, the water
boils with great violence, and a large portion of
it may in this manner be readily raised in vapour,
which is as soon condensed by the cold of the
surrounding medium, and falls upon the leather
of the pump-plate. The reason of this is, that
the greatest heat water is susceptible of, or its
boiling heat, depends upon the pressure of the
air upon its surface; the less the pressure, the
less is the boiling heat; and whenever it arrives
at the boiling heat, the greater heat applied to
augment its temperature, instead of doing so,
converts a portion of it into vapour, which, as
has been remarked, absorbs a great quantity of
heat, without any increase of temperature†.

As this variation of temperature in boiling
water according to the different pressure of the
air, is a circumstance not foreign to the subject
we are upon, and perhaps the quantity and mode
of the variation may not be generally known,
we shall here introduce the result of a series of
experiments made in order to ascertain what
pressure upon the surface of water is requisite
to make it boil at a given temperature; having
never seen any similar account, though the thing
has

* See a note upon this subject, page 136.

† Hence we see the reason of the proviso, page 20, in
determining the boiling point of thermometers.

has probably been done by others with more accuracy.

Heat of the water when boiling.	Pressure upon its surface, in inches of mercury.	Rarefaction of the air.
212°	30.00	1
200	22.8	1.3
190	18.6	1.6
180	15.2	2
170	12.2	2.45
160	9.45	3.2
150	7.48	4
140	5.85	5.1
130	4.42	6.8
120	3.27	9.2
110	2.52	11.9
100	1.97	15.2
90	1.47	20.4
80	1.03	29

N. B. M. *De Sauſſure* found the heat of boiling water upon the ſummit of mount *Blanc*, 186°; the height of the mountain is near 3 miles above the level of the ſea; the barometer was 16 inches $\frac{134}{80}$ of a line (a little above 17 Engliſh inches.

Experiments of this ſort, when made with all the accuracy they will admit of, I am inclined to think will lead to the true theory of evaporation, and to the ſtate of vapour in the atmoſphere; upon conſideration of the facts, it appears to me, that evaporation and the condenſation of vapour are not the effects of chymical affinities, but that aqueous vapour always exiſts as a fluid *ſui generis*, diffuſed amongſt the reſt of the aerial fluids.

fluids.——It is true, the fact that a quantity of common air of a given temperature, confined with water of the same temperature, will only imbibe a certain portion of the water, and that the portion increases with the temperature, seems characteristic of chymical affinity; but when the fact is properly examined, it will, I think, appear, that there is no necessity of inferring from it such affinity.

Granting the truth of the preceding experiments, when the incumbent air is rarefied 29 times, water of 80° is at the point of ebullition; or, in other words, aqueous vapour of the temperature of 80°, can bear no more than 1.03 inches of mercury, without condensation; this, then, is the extreme density of the vapour of that temperature. Now, when a quantity of atmospheric air of 80° imbibes vapour, the vapour is diffused through it, and it may therefore continue to imbibe till the density of the vapour, considered abstractedly, becomes $\frac{1}{29}$ of what it is when under the pressure of 30 inches of mercury, and its temperature 212°; or, till $\frac{1}{29}$ of the bulk of the compound mass is vapour, and then it will be saturated, or imbibe no more; because if it did, the density of the vapour must be increased, which it cannot be in that temperature, without losing its form, and becoming water. Thus then it appears, that upon this hypothesis, there is no need to suppose a chymical

mical attraction in the cafe; and further, that a cubic foot of dry air, whatever its denfity be, will imbibe the fame weight of vapour if the temperature be the fame; and laftly, that it may be determined *a priori*, what weight of vapour a given bulk of dry air will admit of, for any temperature, provided the fpecific gravity of the vapour be given. For example, let it be required to find the weight of vapour which a cubic foot of dry air of 80° will admit of, or imbibe, fuppofing the fpeeific gravity of air .0012, and that of vapour to air as 3 to 4 :—A cubic foot of water weighs 437500 grains, and the fpecific gravity of vapour from the *data*, is .0009; now the compound mafs being denoted by q, we fhall have $\frac{1}{29}q$ = the vapour, and q = 1 foot + $\frac{1}{29}q$; that is, $q = \frac{29}{28}$ foot; and the vapour = $\frac{1}{28}$ foot, = 14 grains. This, it will be obferved, is the refult of the *hypothefis*. M. *De Sauffure* determined by the *experiment* alluded to, page 104, that a cubic foot of dry air of 66° would imbibe 11 or 12 grains of water. Hence then it feems probable that the hypothefis would agree with experiment.—By a like procefs, we fhall find the weight of vapour imbibed by a cubic foot of air of 150°, equal to 131 grains. *

Evaporation

* I cannot forbear remarking in this place, that the fact obferved by Dr. *Darwin*, in the Philofophical Tranfactions for 1788, fupports the theory we have here advanced, and indeed, I think, cannot be fo rationally accounted for on any other: the fact was, that air during its rarefaction attracts

heat.

Evaporation from land in general muſt be leſs than the rain that falls upon land; otherwiſe there could be no rivers. In winter the evaporation is ſmall, compared to what it is in ſummer. From a ſeries of experiments made in the preſent year, 1793, I found the mean daily quantity evaporated from a veſſel of water, in a ſituation pretty much expoſed to wind and ſun, for 13 days of March, to be .033 of an inch in depth, the greateſt .064; for 21 days of April the mean daily quantity was .0555 of an inch, the greateſt .1115; for 26 days of May the mean was .0755, the greateſt .1346; for 14 days of June the mean was .063, the greateſt .098; for 8 days of July the mean was .122, the greateſt .195: I never found the evaporation from water any ſummer much to exceed .2 of an inch in 24 hours, in the hotteſt weather. From theſe experiments, and other conſidera-

T   tions,

heat from the ſurrounding bodies, and gives off heat during its condenſation; now, the moment any quantity of atmoſpheric air is rarefied, its vapour muſt be rarefied alſo, and hence a portion of moiſture will expand into vapour in order to reſtore that ſtate of denſity which the temperature admits of, and abſorb the requiſite quantity of heat from the bodies adjacent; again, the moment air is condenſed, its vapour is condenſed proportionally, ſo that the abſolute quantity of vapour which retains its form, will always be as the *ſpace* occupied by the condenſed air, and the reſt will be precipitated, giving off its heat to the ſurrounding bodies.—Notwithſtanding what is here ſaid, it is probable that a decreaſed preſſure upon the ſurface of water *accelerates*, if it do not increaſe the evaporation, all other circumſtances being the ſame.

tions, it feems probable, that the evaporation both from land and water, in the temperate and frigid zones, is not equal to the rain that falls there, even in fummer.

When a precipitation (or condenfation, which ever it be) of vapour takes place, if the temperature of the air be above 32°, the matter precipitated is liquid, or in form of *rain;* but if the temperature of the air be lefs than 32°, it is in form of *fnow;* when drops of rain, in falling, pafs throw a *ftratum* of air below 32°, they are congealed, and form *hail.*

If we adopt the opinion, which to me appears the more probable, that water evaporated is not chymically combined with the aerial fluids, but exifts as a peculiar fluid diffufed amongft the reft; whenever any condenfation of it happens, the matter muft be *precipitated,* though not in the chymical fenfe of the word; we would therefore be underftood in this effay to ufe the words *precip.tation* and *precipitated* merely to denote the effect, without any allufion to chymical agency.

Different theories to account for thefe precipitations from the atmofphere have been formed; but the principles of none appear to me to be more plaufible, and confiftent with facts, than that which has lately been offered to the public, in the *Edinburgh Philofophical Tranfactions,*

by

by Dr. *Hutton* of that place. From a fhort review of the article (for I have not feen the original) it appears, that he confiders the varieties of heat and cold, affecting the folvent power of the atmofphere, as the fole caufes of rain. Indeed, when we confider that evaporation and the precipitation of vapour are diametrically oppofite, it is reafonable to fuppofe that they fhould be promoted by oppofite caufes; and as heat and dry air are favourable to evaporation, fo cold, operating upon air replete with vapour, promotes its precipitation. The point upon which we differ, I fuppofe will be, that he confiders water chymically combined with the atmofphere, and that cold produces a precipitation in a manner fimilar to what it does in water faturated with falt, or in other chymical proceffes; whereas I fuppofe, that a portion of the vapour, confidered as a diftinct and peculiar fluid, is condenfed into water by cold; the effects refulting from the two theories will therefore be much the fame.

The reafon then that a SW. wind in thefe parts brings rain, feems to be, that, coming from the torrid zone, it is charged with vapour, and the heat efcaping as it proceeds northward, a precipitation of the vapour enfues; but a NE. wind, blowing from a cold into a warmer country, has its capacity for vapour increafed, and therefore we generally find it promote evaporation.

From

From the obfervations upon the quantity of rain that falls in different places, it feems clearly afcertained, that there is more rain in mountainous than in level countries. The reafon feems to be, that the inferior, warm, and vapoury *ftrata* of air, ftriking againft the mountains, are made to afcend into the colder regions, by which means the vapour is precipitated : the fituation of places, however, may be too high to experience an extreme in this refpect ; thus, the rain in *Switzerland*, and amongft the *Alps*, is not probably greater than in the north of *England*. It is more than probable too, that the rain in places fituate near the weftern coaft of *Great-Britain*, and of the Continent, is greater than in the more inland parts. Mr. *Clark*, in his Letters on the Spanifh Nation, obferves, that there was an inftance when no rain fell in *Caftile* for 19 months together ; the province is in the centre of *Spain*, and at a great diftance from the fea.

In the level parts of this kingdom, and in the neighbourhood of the metropolis, the mean annual rain is only 19 or 20 inches.

Profeffor *Muffchenbroek* has given us an account of the mean annual rain at feveral places, which we fhall fubjoin, together with an account from fome other places. The inches differ a little in different countries, but the difference is too trivial to merit much notice in this place.

Mean

	Mean annual rain. Inches.
Utrecht, Haerlem, and Lifle, each	24
Delf, and Harderwick, each	27
Dort	40
Middleburgh, in Zealand	33
Paris	20
Lyons	37
Rome	20
Padua	$37\frac{1}{2}$
Pifa	$34\frac{1}{4}$
Zurick, in Switzerland	32
Ulm, in Germany	$26\frac{5}{8}$
Wittenberg	$16\frac{1}{2}$
Berlin	$19\frac{1}{2}$
In Lancafhire	41
Upminfter, in Effex	$19\frac{1}{2}$
Bradford, in New England (2 years)*	31.4
Langholm, } in Scotland†	36 +
Branxholm, }	31 +
Kendal	64.5
Kefwick	68.5

From the table of the mean monthly rain at *Kendal* and *Kefwick*, page 38, it appears, that if we would pitch upon 6 fucceffive months, which together produce more rain than any other 6 fucceffive months, at thefe places, we muft begin with September. At *Kendal*, from September to March there is 37.6 inches of rain, and from March to September only 26.9 inches; at *Kefwick*, the rain in the former period a-

mounts

* American Philofophical Tranfactions.

† Edinburgh Philofophical Tranfactions.

mounts to 40.4, and in the latter to 28.1.—
The reason of this seems to be, that, in the former
period, the temperature of the air is decreasing, and consequently its capacity for vapour
also; which circumstance is an additional cause
of the precipitation of vapour. In the latter
period, the capacity of the air for vapour is increasing, which occasions a less precipitation.

When a precipitation of vapour takes place,
a multitude of exceedingly small drops form a
cloud, mist, or fog; these drops, though sometimes denser than the air, at first descend very
slowly, owing to the resistance of the air, which
produces a greater effect as the drops are smaller,
as may be proved thus:— Let $d =$ the diameter
of a small drop, and $nd =$ that of a larger; then
the resistances, being as the squares of the diameters when the velocity is given, will be as d^2
and $n^2 d^2$, respectively; but the magnitudes are
as d^3 to $n^3 d^3$, or as 1 to n^3, whence, if the large
drop be divided into others of the same magnitude as the small one, the number will be $= n^3$,
and the resistance to them falling, as $n^3 d^2$, whilst
the resistance to an equal mass in one drop is as
$n^2 d^2$; consequently, the resistance to the large
drop is to the resistance of all the small ones,
moving with the same velocity, as the diameter
of one small drop is to the diameter of the large
one, and the force being constant, the time of
falling through a given space will be greater
when

when the drops are fmall than when large.
From this it appears, that clouds confifting of
very fmall drops may defcend very flowly, which
is agreeable to obfervation; if the drops in fal-
ling enter into a *ftratum* of air capable of im-
bibing vapour, they may be rediffolved, and the
clouds not defcend at all; and if the air's capa-
city for vapour increafe, they may be all im-
bibed, and the cloud entirely vanifh. On the
other hand, if the precipitation go forward, and
the air below have its full quantity of vapour,
the fmall drops meeting one another, will co-
alefce, and form larger ones, and defcend in
form of rain to the earth's furface.—What is
faid of rain, will likewife hold of fnow, except
that the fmall particles coalefcing form flakes, by
reafon of their not being fluid*.

From the important obfervations on the height
of the clouds (page 41) we learn, that they are
feldomer above the fummit of *Skiddaw*, in Nov.
Dec. Jan. and Feb. than in the other months;
this clearly indicates the effect of cold in re-
ftraining the afcent of vapour. Were the mea-
furement extended above the fummit of the
mountain, it is probable, from the apparent law
of the table, that there could not be many ob-
fervations

* This account of the nature of clouds, and of the mode
of their rifing and falling in the atmofphere, was fuggefted
by a philofophical friend and acquaintance; and it appears
to me very rational and confiftent.

fervations above 1300 yards in winter, nor above 2000 yards in fummer. This, it muſt be obſerved, relates to the height of the *under* furface of the groſs clouds only. The ſmall white ſtreaks of condenſed vapour which appear on the face of the ſky in ſerene weather, I have, by ſeveral careful obſervations, found to be from 3 to 5 miles above the earth's furface.

When vapour is condenſed into ſmall drops upon the furfaces of bodies on the ground, it is called *dew*; the only ſeeming difference betwixt dew and rain is, that the condenſation of the vapour in the one caſe is made at or near the furface of the body receiving it, and in the other the drops fall a conſiderable ſpace before they reach the earth; the cauſe is the ſame in both caſes, namely, cold, operating upon vapoury air. At firſt view it will ſeem inconſiſtent that a condenſation of vapour ſhould take place in the air reſting upon the earth's furface, which is generally ſuppoſed to be warmer than that above; but it is an inconteſtable fact, that after ſun-ſet, and during the night, in ſerene weather, the air is coldeſt at the earth's furface, and grows warmer the higher we aſcend, till a certain moderate height (perhaps from 20 to 100 yards, or upwards), this I have often obſerved myſelf, before I happened to ſee it elucidated, by a ſeries of experiments, in the *Lettres phyſiques, &c.* Tom. 5, page 561. And accordingly we find, that

dew

dew and hoar frost are more copious in valleys than in elevated situations. That dew depends upon this circumstance can hardly be doubted, because when clouds or winds prevent it, there is little or no dew formed.

We should scarcely be excused, in concluding this essay without calling the reader's attention for a moment to the beneficent and wise laws established by the Author of Nature, to provide for the various exigencies of the sublunary creation, and to make the several parts dependent upon each other, so as to form one well regulated system, or whole.—In the torrid zone, and we may add in the temperate and frigid zones also, in summer, the heat produced by the action of the solar rays would be insupportable, were not a large portion of it absorbed, in the process of evaporation, into the atmosphere, without increasing its temperature; this heat is again given out in winter, when the vapour is condensed, and mitigates the severity of the cold. The dry spring months are favourable to agriculture, and the evaporation, which then begins to be considerable, absorbs a portion of the heat imparted to the earth by the sun, and thus renders the transition from cold to heat slow and gradual; in autumn the sun's influence fails apace, and the condensation of vapour contributes to keep up the temperature, and prevent too rapid a transition to winter.

ESSAY SEVENTH.

On the Relation betwixt the Barometer and Rain.

SINCE the barometer has become an instrument of general use, and is adopted as a guide by most people interested in the state of the weather, it may be of service to investigate the relation subsisting betwixt the weight of the atmosphere and its disposition for rain, from the facts afforded us by observation,—and we may at the same time consider what further arguments can be obtained in support of the foregoing theories.

In the first place it is remarkable, that, from the table of the mean state of the barometer for 5 years, in page 16, we find the highest mean upon 6 successive months obtained from March to August, inclusive; that is, the mean state of the barometer for March, April, May, June, July, and August, taken together, is greater than for any other 6 successive months, being at *Kendal*, for instance, 29.83, and for the remaining 6 months, only 29.75. But what is more particularly worthy of notice, is, that in this respect, the rain and the barometer are just the reverse of each other; for, in the former period

the

the rain was leaft, and greateft in the latter, as has been obferved, in page 141.

Again, by recurring to the tables, page 16 and 38, we fhall obtain the following arrangements of the months, beginning with that on which the mean ftate of the barometer was higheft, and proceeding regularly on to the loweft; and again, beginning with that month on which there was leaft rain, and proceeding to that on which there was moft.

Barometer high.	*Barometer low.*
May, Aug. June, Mar. Sept. April.	Nov. Feb. Octo. July, Dec. Jan.

Dry months.	*Wet months.*
Mar. June, May, Aug. April, Nov.	Octo. Feb. July, Sept. Jan. Dec.*

Now it is obfervable, that the evaporation is greateft from March to Auguft; confequently, the air is then farther from the point of faturation, or has a greater capacity for vapour, than in the other period; or, in other words, it is drier, relative to its temperature, than in the other period.——Hence then we have a ftrong ar-

V 2   gument

* By making the arrangements for *Kendal* alone, and taking in the prefent year, 1793, till Auguft, and part of 1787, we obtain the following:

Bar. May, Aug. June, Mar. Sep. April, Nov. Feb. July, Oct. Jan. Dec.

Rain. Mar. May, June, April, Aug. Oct. Nov. Feb. Sep. July, Jan. Dec.

gument for the theory of the barometer, as well as for that of rain.

But to be more particular in the investigation: —It will be seen that there have been 6 months when the mean state of the barometer at *Kendal* was 30 inches or above; 9 months when it was 29 9, or from thence to 30 inches; 17 months when it was 29.8, or from thence to 29.9, &c. as per the following table.—Now, in order to examine the relation of the barometer and rain, it will be proper to find the mean monthly rain for those distributions of the months when the mean state of the barometer was nearly the same. This we have done, and the result follows.

Mean state of the barometer, at Kendal.	Number of months.	Mean monthly rain in the different distributions, in inches.		
		Kendal.	Keswick.	London*.
30 +	6	2.605	2.511	.212
29.9 +	9	3 362	4 018	.835
29.8 +	17	5 402	5.676	1.846
29.7 +	13	6.184	6.449	2.100
29.6 +	7	7.116	7.198	1.340
29.5 +	6	6.798	7.533	.898
29.4 +	1	3.306	3.600†	3.253
29 3 +	1	8.369	11.357	

The

* The account in this column, is the result of the 3 years' observations we have inserted in the first part; the first mean is for 4 months, when the barometer at *London* was 30.1 plus; the second for 6 months, when it was 30 plus, &c. the rest are for 7, 11, 5, 2, and 1 months, respectively.

† There was no rain-gauge this month at *Keswick*; the quantity set down is got by comparison only.

The inferences to be drawn from this table are, 1ft, The higher the barometer is above its mean annual ftate, the lefs rain there is. 2d. The farther it is below its mean annual ftate, the more rain there is, till it comes to a certain point, after which the rain feems to decreafe again.

The firft of thefe inferences, being conformable to common obfervation, was expected; but the conclufion in the fecond, that the monthly mean ftate of the barometer may be *too low* to be attended with the *maximum* of rain, was not apprehended till the preceding table, which feems to warrant it, was digefted. However, it was immediately perceived, that the point might be cleared up, by felecting all thofe days which have produced the greateft quantity of rain, and finding the mean ftate of the barometer upon thofe days, which may be taken for that ftate moft conducive to the greateft quantity of rain. —The refult of a careful examination of my own obfervations, at *Kendal,* follows: during the extraordinary fall of rain on the 22d of April, 1792, (fee page 38) the mean of the barometer was 29.62; the other 2 days that gave more than 2 inches of rain each, the barometer was 29.59 and 29.33 refpectively: as for the other 56 days, on each of which there was more than 1 inch of rain, the mean ftate of the barometer upon the whole of them was 29.47, and for 54

of

of thofe days the barometer was between 29.99 and 29.81; the barometer on the other 2 days was plainly irregular, being on the one 28.5, and it is remarkable, that the rain of that day was barely 1 inch; on the other it was 30.06, attended with an extraordinary circumstance. (See page 44, upon June 4, 1791).

From this it appears, that the heavieſt rain may be expected when the barometer is about 29.47, at this place, or, in round numbers, 29½ inches, which is a little *above* the mean of the two great extremes obſerved in January 1789, or 29.44.

In the laſt 5 years there have been 1827 days, of which 1082, as per account, had rain, more or lefs, at *Kendal*, and 59 of thoſe gave above 1 inch of rain each; hence, at an average, there has been 1 of ſuch days in every 31, wet and fair, and in every 18 wet days, nearly. The number of days when the mean ſtate of the barometer was below 29 inches, were 45, of which 2 only were fair; and yet there was but 1 of thoſe that gave 1 inch of rain. From theſe facts we may conclude, that when the barometer is very low, the probability of its being fair is much ſmaller than at other times; but that, on the other hand, the probability of very much rain, in 24 hours, is not ſo great as at other times, which is confiſtent with the concluſion

obtained

obtained from the facts stated in the preceding paragraphs.

Upon an enumeration it appears, that there have been 78 days in the different months of the last 5 years when the mean state of the barometer, at *Kendal*, was above the usual high extreme for the month, as stated at page 16; only 7 of those days were wet, and the rain in very small quantities; hence, the probability of a fair day at that place, to that of a wet one, in such circumstances, is as 10 to 1.

The preceding facts offer nothing but what appears consistent with the theories of the barometer and rain; when the barometer is above the mean high extreme for the season of the year, the air must, relatively speaking, be extremely *dry* or *cold*, or both, for the season; if it be extremely dry, it is in a state for imbibing vapour, and if it be extremely cold, no further degree of cold can then be expected, and therefore in neither case can there be any considerable precipitation: on the contrary, when the barometer is very low for the season, the air must relatively be extremely *warm* or extremely *moist*, or both; if it be extremely warm, it is in a similar state to dry air for imbibing vapour, and if it be extremely moist, there must be a degree of cold introduced to precipitate the vapour, which cold, at the same time, raises the

the barometer. From which it follows, that no very heavy and continued rains can be expected to happen whilst the barometer actually remains about the low extreme, but they must rather be the consequence of a junction or meeting of extremes, which at the same time effects a mean state of the barometer.

ESSAY

ESSAY EIGHTH.

On *the* Aurora Borealis.

A S this effay contains an original difcovery, which feems to open a new field of enquiry in philofophy, or rather, perhaps, to extend the bounds of one that has been, as yet, but juft opened; it may not perhaps be unacceptable to many readers to flate briefly the train of circumftances which led the author to the important conclufions contained in the following pages.

It will appear, from the obfervations, that the author has been pretty affiduous, during the laft 6 years in noticing thofe very fingular and ftriking phenomena, the *auroræ boreales*, as often as they occurred; in which time he has alfo feen and confidered, with a proper attention, feveral conjectures and hypothefes, endeavouring to account for them; but as no hypothefis has yet appeared that explains the general phenomena in fuch a manner as to procure the acquiefcence of any rational enquirer, it was natural to expect that his attention would occafionally be turned towards an inveftigation of the nature and caufe of the *aurora*.

X

It

It seemed to be sufficiently proved that the *aurora* was not without the earth's atmosphere, though he had never seen any thing done which ascertained the real height of any one appearance with a tolerable degree of accuracy; and as the atmosphere, or at least the prof part of it, is in all probability confined to the height of 15 or 20 English miles, he was unwilling to admit of the greater height of the *aurora*, unless compelled to it by the result of careful and accurate observations. The prevailing idea too that the *aurora* may be *heard*, was another means to induce him to think it was at a moderate height. —Appearances, however, were in direct opposition to the thought;—that one and the same *aurora* should be seen over a vast extent of country, with much the same circumstances, and that some of them should appear in *France*, *Spain*, and *Italy*, whilst they so very seldom pass our zenith in the north of *England*, was a very strong argument for their great height. The best observations likewise upon those large fiery meteors which occasionally fly over the country, and are seen at such distant places, seem to prove the existence of an elastic fluid at the height of 60 or 80 miles at least, which far exceeds the height of the atmosphere as prescribed by the observations upon the barometer, or even by the twilight; and if the atmosphere exceed the height of 45 or 50 miles, as determined by the observations on the duration of twilight,

twilight, we have no *data* from whence to fix its bounds; it may, for ought we know, amount to 4 or 5 hundred miles.

These confiderations, it is evident, could not fail of fuggefting to the author the expediency of determining, by actual obfervations, the real height of the *aurora borealis*. This he thought might be accomplifhed by the affiftance of his friend and colleague in the bufinefs, Mr. *Crofthwaite*, of *Kefwick*, who having for a long time been accuftomed to make fuch obfervations, was the more eligible for the purpofe; but the manner of doing it was firft to be determined upon, as the great difficulty was to afcertain that the obfervations were cotemporary, and made upon one and the fame object.

As the *aurora* often confifts of upright beams, efpecially when high above the horizon, and thefe feldom continue one minute the fame, the queftion was, whether to attempt the altitude of the bafe of the beams, or the vertex, or both; this put the author upon confidering more particularly what the real form of the beams is when ftript of the optical illufion, which muft accompany all objects feen at a great diftance in the atmofphere, namely, that of appearing to coincide with the blue vault, or fky, and to conftitute a part of its fpherical furface. A very moderate fkill in optics was fufficient to convince him, that as the

X 2 luminous

luminous beams at all places appear to tend towards one point about the zenith, they muſt in reality be ſtraight beams, parallel[*] to each other, and nearly perpendicular to the horizon ; and from the appearance of their breadth, they muſt be cylindrical. Theſe circumſtances accounted at once for the *aurora* appearing ſo denſe northward, towards the horizon, and the beams being ſo thin and ſcattered towards the zenith, which is ſo uniformly the caſe. Moreover, as the beams appear to riſe above each other in regular ſucceſſion one ſet above another, in ſuch ſort, that the higher the baſes of the beams are, the higher are their vertices, it ſeemed from this circumſtance probable, that they are all of the ſame length and height; if this be the caſe, by determining the greateſt angle ſubtended by the beams, the relation or proportion of their length to their height above the earth's ſurface may be determined geometrically.—This circumſtance deſerved to be kept in view; and it appeared, from obſervations made upon the *aurora* afterwards, that though the fact could not eaſily be aſcertained, yet ſo much was certain, that the length of the beams bore a very great proportion to their diſtance from the earth, even ſo as to equal or perhaps ſurpaſs the ſaid diſtance.

Thus

[*] The author did not ſee, before May 1793, the Philoſophical Tranſactions for 1790, in which he finds this idea is ſuggeſted by *H. Cavendiſh,* Eſq. F. R. S. and A. S.

Thus stood the author's knowledge and ideas upon the subject in the autumn of 1792.—The very grand *aurora* in the evening of the 13th of October, was that which first suggested and led to the discovery of the relation betwixt the phenomenon and the earth's magnetism. When the theodolite was adjusted without doors, and the needle at rest, it was next to impossible not to notice the exactitude with which the needle pointed to the middle of the northern concentric arches: soon after, the grand dome being formed, it was divided so evidently into two similar parts, by the plane of the magnetic meridian, that the circumstances seemed extremely improbable to be fortuitous; and a line drawn to the vertex of the dome, being in direction of the *dipping-needle*, it followed, from what had been done before, *that the luminous beams at that time were all parallel to the dipping-needle.* It was easily and readily recollected at the same time, that former appearances had been similar to the present in this respect, that the beams to the east and west had always appeared to decline considerably from the perpendicular towards the south, whilst those to the north and south pointed directly upwards, the inference therefore was unavoidable, that the beams were guided, not by gravity, but by the earth's *magnetism*, and the disturbance of the needle that had been heretofore observed during the time of an *aurora*, seemed to put the conclusion past doubt. It

was

was proper however to obferve whether future appearances correfponded thereto, and this has been found invariably the cafe, as related in the obfervations.

Soon after this, the author wrote to Mr. *Crofthwaite*, defiring him to pay particular attention to thefe phenomena for a feafon, to take the bearings, altitudes, times, &c. of every remarkable appearance, and to obferve the point to which the beams converged, the bearing of the perpendicular beams, the extent and bearing of the large, northern, horizontal lights, &c. Thefe he performed with much readinefs and fkill, and his obfervations agree fufficiently with thofe made at *Kendal*, though he was entirely unacquainted with the difcovery, and confequently his obfervations could not be warped to fuit the author's purpofe.

The obfervations on the 15th of February, 1793, are thofe upon which the height of the *aurora* refts principally, as none of the others were fufficiently well timed and circumftanced to be fubfervient to this purpofe, except perhaps that on the 30th of March, 1793. *

We

* It may not be improper here to advert to a circumftance, which, if not noticed, may be a means of fubjecting the author, in fome degree, to the imputation of plagiarifm. ——The advertifements refpecting this work were printed on the 10th of April, 1793, in which the difcovery above

mentioned

We shall now proceed to state the different parts of this essay, disposing them into separate sections, as follows.

SECTION

mentioned was announced as an original one, and never before published; the author not knowing that any one had published the most distant intimation of their ascribing the phenomena of the *aurora borealis* to magnetism. On the 17th of said month, *George Birkbeck*, of *Settle*, an ingenious and intelligent young man, a subscriber to this work, informed the author, that an anonymous person, in a certain periodical publication, had given an essay on the *aurora borealis*, in which, amongst other conjectures, he had advanced the opinion that it might be occasioned by the earth's magnetism;—he was so obliging as to transmit the author a copy of the essay itself, which may be seen in a work entitled *Mathematical, Geometrical, and Philosophical Delights*, No. 1." published May 1, 1792, under the inspection of a Mr. *Whiting*.

The author, who subscribes himself *Amanuensis*, states his conjectures to the following purport, viz.

1st. He supposes that magnetic effluvia are constantly issuing from the earth's magnetic pole in the north, and that these effluvia, which he considers of a ferruginous nature, fly off in every direction along the magnetic meridians; he then conjectures that the sulphurous vapours, rising from the many volcanos in the north, mixing with the magnetic effluvia, may catch fire, and fulgurate.

2d. He conjectures that inflammable air having caught fire, may receive a magnetic direction, by the current of magnetic effluvia; he subjoins to this conjecture, some very just observations on the *aurora*, which we shall have occasion to mention hereafter.

3d. He conjectures that " a highly subtilized aerial nitre " always enters into the composition of an *aurora*."

4th.

SECTION FIRST.

*Mathematical Propositions neceffary for illuftrating
and confirming thofe concerning the
Aurora Borealis.*

PROPOSITION I.

ALL lines or fmall cylinders, whether ftraight,
curved, or crooked, feen at a confiderable dif-
tance in the atmofphere, and fituate within a
plane paffing through the eye, muft appear
arches

4th. That the *aurora*, like lightning, may be of an elec-
tric nature.

5th. He afks, " May the luminofity be conveyed on the
" magnetic effluvia, as the electric on an iron wire ?"

6th. He conceives the reafon why the *aurora* is fo frequent
now is, becaufe there are more volcanos in the north.

I fhould fuppofe that thefe conjectures, as far as they refer
the phenomena of the *aurora borealis* to magnetifm, are ori-
ginal; and from the time of the publication it might be fuf-
pected that I received the firft hint from it; this however
was not the cafe, this work being nearly ready for the prefs
before the 10th of April, and it was not till after, that the
letter containing the effay came to hand, which firft furnifhed
me with the preceding conjectures; befides, it will be feen
that my opinions are, for the moft part, very different from
thofe ftated above.———It is not meant by this to depreciate
the merit of the ingenious *Amanuenfis*, who will probably be
well fatisfied to fee that the fuppofition of a relation be-
tween the *aurora borealis* and magnetifm, which probably
firft occurred to him, is capable of being proved to a de-
monftration.

arches of a circle, in whose centre is the eye, bounded by lines drawn from the eye to the extremities of the objects.
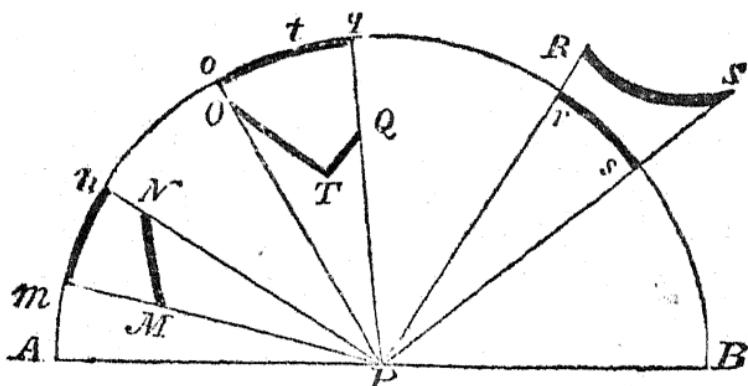
DEMONSTRATION.

The semicircle *A m n o t q r s B P* represents a part of any plane passing through the eye, supposed to be at *P*, the centre; *A P B* the intersection of the said plane with the plane of the horizon; the arch of the semicircle represents the intersection of the first mentioned plane with the blue canopy or sky; *MN, OTQ,* and *RS* represent three cylindrical beams seen at a distance, whose axes are in the plane *A m n o t q r s B P* indefinitely extended. Then the object *MN* being at a considerable distance, as 5, 10, &c. miles, and quite detached from all objects on the earth's surface, it follows, from the principles of optics, that the mind cannot judge with certainty either of the absolute distance of the object, or whether the extremity *M* or *N* is more distant; in such a case, therefore, nothing appears to the contrary but that both ends are equally distant, and that *MN* is an arch of a circle in the sky, with the eye in the centre; and this in fact is the judgment that is uniformly made in the case. For it is known to every one, that celestial objects, and objects at a distance in the air, as the sun,

Y

moon,

moon, ftars, meteors, &c. all *appear* at the fame diſtance, though nothing can be more diſproportionate than their real diſtances; that is, they all appear as if ſituate in the ſky: hence then the objeƈt *MN* will appear as the arch *m s*, *OTꝖ* as the arch *o t q*, and *RS* as the arch *r s*.   Q. E. D.

Corollary 1. Hence it may eaſily be deduced, that no line that is not wholly ſituate in a plane paſſing through the eye can appear as the arch of a great circle.

Corollary. 2. Hence alſo it follows, that if an objeƈt appear to be the arch of a great circle to two obſervers, ſo ſituate that they two, and the objeƈt, are not all in the ſame plane, the objeƈt muſt be a ſtraight line, or ſmall cylinder, becauſe it muſt neceſſarily be wholly in two planes, and conſequently in their common interſeƈtion, which is a ſtraight line *(Euclid, 11 and 5).*

PROPOSITION II.

Imagine a cylindrical beam, as *A E*, elevated in the air, and viewed from a ſtation on the earth, at a diſtance, as in the laſt propoſition; and ſuppoſe the beam ſo ſituate that a perpendicular *C P* from *C* to the ſide of the cylinder *B E* may fall below *B*, or in the prolongation of *E B*; then, I ſay, the beam will appear broadeſt near the bottom, and narrower as it aſcends, that is, its ſides will appear bounded by the circumferences of two great circles, having their common interſeƈtion in a line *CV* parallel to *BE*.
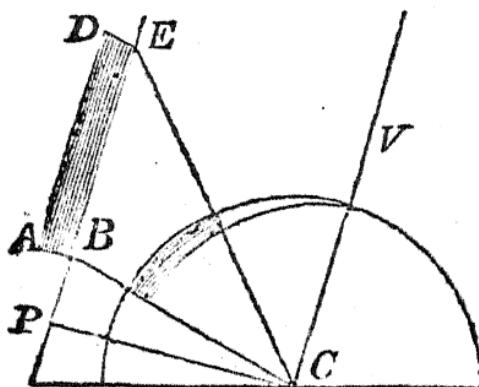
DEMONSTRATION.

By the laſt propoſition the lines bounding the cylinder longitudinally will appear as arches of great circles; and if the line *BE* be ſuppoſed to be extended indefinitely, the angle *PCE* increaſes, and when *BE* becomes infinite, *CE* coincides with *CV*, and the angle *PCV* = a right one; and the very ſame concluſion will follow if a perpendicular be let fall from *C* upon *AD*, or any other line parallel to *BE*; therefore all right angles parallel to *BE* will appear arches of circles, which, if prolonged, would interſect each other in the line *CV*, and the ſpace bounded by any two arches will grow narrower from *P* towards *V*. Q. E. D.

Corollary. If there be a number of beams ranged all over a tranſparent plane parallel to the horizon, at the height of *AB*; and if theſe beams be parallel to the beam *AE*, then they will all appear to converge towards *V*, from every point of the horizon.

Scholium. The appearances of the extremities of the cylinder are not here conſidered; but it would be eaſy to prove they muſt appear elliptical.

PRO-

PROPOSITION III.

Let there be a series of cylindrical beams, DE, KL, &c. equal and parallel to each other, all in a plane perpendicular to the horizon, and at equal distances from the horizon: and let AB be the intersection of the plane with the horizon: HeL its interfection with the sky, C the centre of HeL, the place of obfervation; and Cv parallel to the beams: then, first, the beams will appear to rife above each other fucceffively, in the fky, in fuch fort, that, of any two beams, that which has the higher bafe, will have the higher vertex alfo, except when the beams appear to pafs through, or lie wholly beyond the zenith; fecond, thofe about the zenith will appear broadeft, and thofe nearest the horizon narroweft.
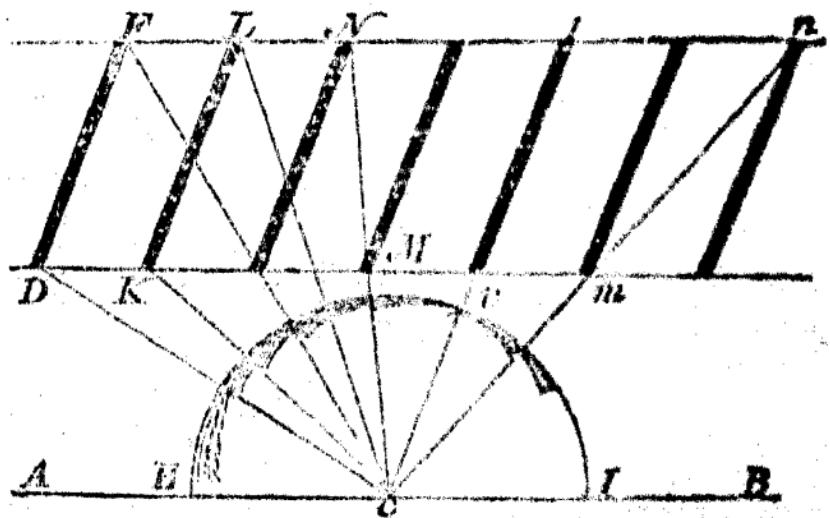
DEMONSTRATION.

Join CD, CF, CK, and CL; then the bafe K will appear higher than the bafe D by the angle DCK, and the vertex L higher than the vertex F by the angle FCL, and fo on for the reft of the beams, till the angle reprefented by FCL is equally divided by a line from C to the zenith; afterwards the contrary takes place. The angle under which the diameter of the beam appears, being fuppofed fmall, will be nearly as the diftance inverfely, and therefore greateft at the zenith, and lefs below, in proportion as radius to the fine of elevation. Q. E. D.

PROPOSITION IV.

The fame Figure remaining.

If the beams are equidiftant, and if CMN, Cmn be drawn on each fide of v, fo as to touch the bafes of two beams in M and m, and the vertices of the two next beams in N and n; then all the beams included in the angle NCn will appear diftinct, and all thofe below, on both fides, will partly cover each other, if opaque; but if luminous, the light of the different beams being blended, will increafe in denfity downward, according to the number of beams croffed by a right line from C.

DEMONSTRATION.

The firft part is obvious, from the elements of geometry; and from the principles of optics, the diftance of the beams makes no difference in their apparent brightnefs, unlefs what arifes from the want of perfect tranfparency in the atmof-

pheres

phere, which fomewhat obfcures diftant objects; hence, the
greater the number of beams croffed by a right line from C,
the denfer will be the light in that direction.   Q. E. D.

PROPOSITION V.

The fame things being fuppofed as in Pro-
pofition third ; let a circle be defcribed through
the extremities of any one beam, as DF, to
touch the horizontal line in c* ; and if cD and
cF be joined, the angle DcF, fubtended by the
beam, will be greater than that fubtended by
any other beam, as feen from c ; and if FD be
produced to meet the horizon in A, and the
quantity of the angle DcF be given, the propor-
tion of AD to DF may be determined.

DYMON*
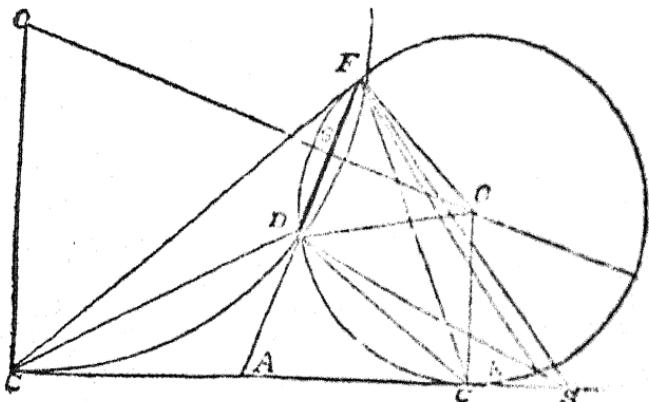
* To do which, fee the laft book of *Simpfon's Geometry,*
prob. 42. third edit.

DEMONSTRATION.

Draw any line, DKS, to cut the circle in K, and meet the horizontal line in S; join FK and FS; then the angle $DKF =$ angle DcF (*Euclid*, 3, 21); and angle DKF is greater than DSF (*Euclid*, 1, 21).

Draw oc perpendicular to the horizon from the centre of the circle o, and bisect DF by the perpendicular oG, and join oD; then, since the angle DcF is given, DoG is given also, being $= DcF$ (*Euclid*, 3, 20); also the angles G and Aco being right, and angle A given by hypothesis, angle Goc is given also, and consequently Doc; and the triangle Doc being isoceles, the angles at D and c are both given, and angle AcD also, being the complement of Dco; whence it will be

Sine AcD : side AD :: sine A : side cD ;

And sine Doc : side cD :: sine Dco : side Do ;

And radius : side Do :: sine DoG : side $DG = \frac{1}{2}DF$, which gives the ratio of AD to DF. Q. E. D.

Scholium. We have here supposed the angle A acute; but if it be taken obtuse, or the observations be made on the other side of A, the proportion of $AD : DF$ may be found equally, but the greatest angle under which the beams appear will be less; thus, if oG be produced to O, so that upon O, as a centre, a circle may be described to pass through F and D, and touch the horizontal line in C; then, the greatest angle DCF will be at C, where the circle touches the horizontal line, as before.

SECTION

SECTION SECOND.

Phenomena of the Auroræ Boreales.

THE appearances of the *aurora* come under
four different defcriptions.———Firft, a *horizontal
light*, like the morning *aurora*, or break of day.
——Second, fine, flender, luminous *beams*, well
defined, and of denfe light; thefe continue $\frac{1}{4}$, $\frac{1}{2}$,
or 1 whole minute, fometimes at reft apparently,
but oftener with a quick lateral motion.——Third,
flafhes pointing upward, or in the fame direction
as the beams, which they always fucceed; thefe
are only momentary, and have no lateral mo-
tion, but they are generally repeated many times
in a minute; they appear much broader, more
diffufe, and of a weaker light, than the beams;
they grow gradually fainter till they difappear.
Thefe fometimes continue for hours, flafhing at
intervals.——Fourth, *arches*, nearly in the form of
rainbows; thefe, when complete, go quite acrofs
the heavens, from one point of the horizon to
the oppofite point.

When an *aurora* takes place, thofe appear-
ances feem to fucceed each other in the following
order :——Firft, the faint rainbow-like arches;
fecond, the beams; and, third, the flafhes: as
for the northern horizontal light, it will appear
in the fequel to confift of an abundance of
          flafhes,

in the magnetic east and west; moreover, the beams perpendicular to the horizon are only those on the magnetic meridian.

These have been the uniform appearances at *Kendal* for a series of observations past, as has been related; and from recollection, and the notes made upon former appearances, as well as from the inference to be drawn from the later observations, I have no doubt the whole list of the *auroræ* were conformable to this description.

The accounts from *Keswick* corroborate the same; the horizontal light is described as extending from WSW. to ENE. and its highest part in the middle, or NNW. or, when past the zenith, SSE*.—As for the vertical streamers, their declination from the vertical circles being so small, except about the east and west points, it is no wonder if there be some latitude in these observations, when the eye is to judge; we do not find, however, that this latitude has exceeded 10° from the magnetic meridian.

That this phenomenon agrees with the observations made in *England, France, Germany*, &c. in the beginning of this century, when the *aurora* first appeared, we learn from the following extracts from the Transactions of the Parisian Academy.

1707. March 6, between 7 and 10 in the evening, M. *Leibnitz* says an *aurora borealis* was observed at *Berlin;* there were two luminous arches, one above the other, both directly northward,

* The horizontal arches, indeed, do not always appear to extend just to the magnetic east and west, but often to fall short of, and sometimes to surpass those points; the reason is, we judge of its extent from its visibility above the sensible horizon, and the light is either so faint by the great distance, or objects intervene, that we seldom see the extremity of the arch, within 2 or 3° of the horizon; this contracts or enlarges its visible extent amazingly, when the arch makes a small angle with the horizon.

northward, their concavity turned downwards, their chords parallel to the horizon ——The variation of the needle in *Germany*, &c at that time, was very little from the true north

1716 M. *Mirald.* describes the horizontal lights of the 11th, 12th, and 13th of April, as having all the same situation, namely, extend from 45 or 50° W to 35 or 30° east of the meridian.——The variation at *Paris* was then about 1 point westerly.

——March 17 a rainbow-like arch was seen at *Brest;* it extended from E. to W. crossing the meridian south of the zenith, soon after, a horizontal light was seen, extent from NW to NNE

——At *Rouen*, the same night, a horizontal light was seen; its extent from 10° E. to 25 or 30° W

——At *Newark*, in *Nottinghamshire*, it was seen between the NW. and N

One seen at *Copenhagen*, February 1, 1707, is said to have extended from WNW to NNE.

September 12, 1621. *Gassendus* observed an horizontal light, at *Aix*, in *Provence*, it extended between the summer rising and setting.——N. B The variation then was a little to the eastward

1718 March 4 M. *Miraldi* observed an horizontal light; extent from NW. to NE. but declining about 10° more to the west.

These observations, compared with those recently made, sufficiently indicate that the position of the *horizontal lights* and *arches*, changes with the needle, and is now much more westerly than formerly *

It

* Since writing the above, I find in the Philosophical Transactions of the Royal Society for 1790, vol 80. several accounts of the rainbow like arches. In Art 3 Mr *Hey*, after describing several arches, says, " the poles of all the " complete arches which I have seen had a *western* variation from the pole " of the equator "——In Art. 5. Mr. *Hutchinson* describes one seen on the 23d of February, 1784, at *Kimbolton*, (63 miles NNW of *London*) to have extended from ENE. to WSW , and a description of the same appearance, not differing essentially, is given in Art. 4.

It fhould, however, be obferved, that this phenomenon is to be underftood as *general*, rather than *univerfal;* becaufe the *horizontal lights*, and *arches*, are fometimes interrupted, which caufes the *aurora* to be feen occafionally almoft wholly to the eaft or weft of the magnetic meridian ; but on all fuch occafions I have obferved the inclination of the *beams* invariably the fame, in the fame quarter of the heavens, as far as the eye could judge ———In fact, if the *horizontal lights*, &c were not interrupted, the zone of light muft quite furround the northern parts of the earth, at every appearance, which we are pretty certain is feldom, if ever, the cafe.

PHENOMENON III.

That point in the heavens to which the *beams* of the *aurora* appear to converge at any place, is the fame as that to which the fouth pole of the *dipping-needle* points at that place.

Granting the truth of the two preceding phenomena, it follows, that the point of convergency muft be in the magnetic meridian ; and this point, from the beft obfervations I can make, is between 70 and 75° from the fouth ; which agrees with the obfervations at *Kefwick* . and it appears that the *dipping-needle* in *England* points to that part.———My notes upon the *aurora* for 4 or 5 years paft ftate the point of convergency to the fouth of the zenith, when a crown was formed, and I believe the remark has been generally made, wherever the appearance was feen and attended to.———*Kircher* obferved the point 29° fouth of the zenith, at *Berlin*.

In fupport of the two laft phenomena I might alfo quote the ingenious *Amanuenfis* whom I have mentioned in the introduction to this effay ; he fays, " that the lucid columns, " or radiating flafhes of the *aurora borealis* almoft always " fhoot off from the north to the fouth, correfponding in a " great

" great meafure to the magnetic meridian. And I have
" conftantly obferved" (adds he) " the *corona*, concourfe,
" or concentration, if I may fo call it, of thefe lucid rays
" near the zenith, fo much to the eaft of it as anfwered
" nearly to the weftern declination of the common magnetic
" needle,—and I think I never obferved the *corona* to the
" weftward of it.

PHENOMENON IV.

The *beams* appear to rife above each other in
fucceffion, fo that of any two beams that which
has the higher bafe has the higher fummit alfo,
or its fummit nearer the point of concourfe;
the angle fubtended by the length of each beam
is not the fame, it being greateft about half way
from the horizon to the zenith, and lefs above
and below; alfo the beams to the fouth fubtend
lefs angles than thofe to the north, having the
fame altitude.—The greateft angle to the north.
feems to be about 25 or 30°; and that to the
fouth 15 or 20°.

PHENOMENON V.

Every *beam* appears broadeft at or near the
bafe or bottom, and to grow narrower as it
afcends, in fuch fort that the continuation of its
bounding lines would meet in the common cen-
tre to which the beams tend; yet the fummit of
the beam is not flat, but pointed.—The higheft
beams feem about 3° broad, and the loweft 1°.

The

The two laft phenomena are the refult of my own obfer-vations chiefly, but there is fome difficulty and uncertainty in meafuring the angles fubtended by the lower beams, by reafon of their being one behind another; it muft the efore be left to future obfervations to determine more accurately the angles under which the beams appear in different parts of the hemifphere.

SECTION THIRD.

Propofitions concerning the Aurora Borealis.

PROPOSITION I.

THE luminous *beams* of the *aurora borealis*, are cylindrical, and parallel to each other, at leaft over a moderate extent of country.

The beams muft be parallel to each other, from Corol. to Prop. 2, and Corol 2, Prop 1, Sect. 1, and from Phenom. 1. Hence, and from Prop. 2, Sect. 1, and Phenom. 5, they are cylindrical.

PROPOSITION II.

The cylindrical beams of the *aurora borealis* are all *magnetic,* and parallel to the *dipping-needle* at the places over which they appear.

From the Corol to Prop. 2, Sect. 1, and Phenom. 3, it follows, that the beams are parallel to the *dipping-needle*. and as the beams are fwimming in a fluid of equal denfity with themfelves, they are in the fame predicament as a mag-netic bar, or needle, fwimming in a fluid of the fame fpecific

gravity with itself, but this last will only rest in *equilibrio* when in the direction of the *dipping needle*, owing to what is called the *earth's magnetism*, and as the former also rests in that position only, the effects being similar, we must, by the rules of philosophizing, ascribe them to the same cause —— Hence, then it follows, that THE AURORA BOREALIS IS A MAGNETIC PHENOMENON, AND ITS BEAMS ARE GOVERNED BY THE EARTH'S MAGNETISM*.

PROPOSITION III.

The height of the *rainbow-like arches* of the *aurora*, above the earth's surface, is about 150 English miles.

This appears from the calculation made from the observations on the 15th of February, 1793,—but other observations ought to be made at more distant places, to ascertain the height with more precision   Possibly the height may be different at different times†.

PRO-

* I am aware that an objection may be stated to this,—If the beams be swimming in a fluid of equal density, it will be said they ought to be drawn down by the action of the earth's magnetism. Upon this I may observe, that it is not my business to shew why this is not the case, because I propose the magnetism of the beams as a thing demonstrable, and not as an hypothesis. We are not to deny the cause of gravity, because we cannot shew how the effect is produced ---May not the difficulty be lessened by supposing the beams of *less* density than the surrounding fluid.

† Since writing the above, I find Mr *Cavendish* has, in Art. 10 of the Philosophical Transactions for 1790, calculated the height of an arch observed at different places, on the 23d of February, 1784, to be betwixt 52 and 71 miles ---But, with deference, I would remark, that the observations above mentioned appear to me better circumstanced than those upon which his calculation is founded, and therefore the result of them more to be relied upon

PROPOSITION IV.

The beams of the *aurora* are fimilar and equal in their real dimenfions to one another.

This is not capable of ftrict demonftration, for want of more exact obfervations; it is, however, rendered extremely probable from Prop. 3 and 5, Sect. 1, and Phenom. 4 and 5.—Indeed the phenomena are almoft irreconcileable to any other fuppofition.

PROPOSITION V.

The diftance of the *beams* of the *aurora* from the earth's furface, is equal to the length of the beams, nearly.

Allowing the truth of the laft propofition, and comparing Prop. 5, Sect. 1, with Phenom. 4, we fhall find the phenomenon to agree beft with the fuppofition of the equality of the diftance and length of the beams.

We have here fubjoined the refult of a calculation of the angles fubtended by the beams, on three different fuppofitions, namely, 1ft, when the length of the beams is equal to their diftance from the earth; 2d, when the length is but half that diftance; and, 3d, when it is twice the diftance.—The calculation is eafily made by inverting Prop. 5, Sect. 1, and fuppofing the point *c* variable, where we have the ratio of *AD* to *DF*, inftead of the angle *DcF* given; the beams are fuppofed to be thofe in the plane of the magnetic meridian, both north and fouth of the zenith, and their bafes are taken at 10°, 20°, 30°, &c. altitude. The angle *FAc* is fuppofed 72°.

When accurate obfervations fhall be made, I have no doubt the angles on the 2d fuppofition will be found too little, and thofe on the 3d too great.   Angles

Angles AcD & ACD.	AD : DF :: 1 : 1		AD : DF :: 1 : ½		AD : DF :: 1 : 2	
	Angle DcF.	Angle DCF.	Angle DcF.	Angle DCF.	Angle DcF.	Angle DCF.
10°	10° 30	8° 27	5° 14	3° 25	20° 51	15° 23
20	19 32	13 4	10 7	7 16	35 2	21 27
30	24 52	14 12	13 42	8 22	40 10	21 33
40	26 34	12 50	15 33	7 56	39 46	18 27
50	25 36	9 48	15 43	6 16	36 27	13 36
60	22 48	5 43	14 32	3 45	31 23	7 45
70	18 53	1	12 21	0 40	25 26	1 20
80	14 15		9 28		18 58	
90	9 14		6 11		12 18	
100	4 4		2 44		5 24	

Scholium. It is very probable the *rainbow-like arches* are either at the top or bottom of the *beams*, and I am inclined to think they are at the top, not only because their light is faint, but because the beams should be seen at a much greater distance than it seems they are, if they were 300 miles high, or twice the height of the arches; and the observations on the 30th of March, 1793, seem to confirm the opinion of the bases of the beams being 60 or 70 miles high, or about half the height of the arches.

If the summits of the beams be 150 miles high, their bases will, according to this proposition, be 75 miles high, and the whole length of the beams about 75 miles, or, more nearly, 75 miles $\times \dfrac{\text{radius}}{\text{sine of } 72°}$. And if the diameter of the base be $\frac{1}{10}$ of the length, each luminous beam will be a cylinder of $7\frac{1}{2}$ miles in diameter, and 75 miles long*.

A a   N. B.

* If a magnet be required to be made of a given quantity of steel, it is found by experience to answer best when the length is to the breadth as 10 to 1 nearly: it is a remarkable circumstance that the length and breadth of the magnetic beams of the *aurora* should be so nearly in that ratio.—— Query, if a fluid mass of magnetic matter, whether elastic or inelastic, were swimming in another fluid of equal density, and acted on by another magnet at a distance, what form would the magnetic matter assume? Is it not probable it would be that of a cylinder, of proportional dimensions to the beams of the *aurora?*

N. B. An object elevated 75 English miles may be seen at the distance of 10 geographical degrees; if elevated 150 miles, it may be seen 14°; if 300 miles, 20°.

PROPOSITION VI.

That appearance which we have called the *horizontal light*, and which is always situate near the horizon, is nothing but the blended lights of a group of *beams*, or *flashes*, which makes the appearance of a large luminous zone.

The figure to Prop. 3, Sect. 1, represents a series of beams such as those of the *aurora*, situate in the plane of the magnetic meridian, and *C* the place of observation. And it is proved in Prop. 4, Sect. 1, that the lights of the distant beams in that plane will be blended, to a certain elevation, to the observer at *C*. Imagine a series of planes parallel to the plane of the magnetic meridian, with beams situate in them likewise; then, from the principles of optics, the rows of beams in every two of the planes will appear to approach each other, as the distance from the observer increases; and when that distance becomes indefinitely great they will all seem to coincide; hence the beams will appear blended, both horizontally and perpendicularly, and will consequently constitute a large zone of dense light. This zone must appear at right angles to the magnetic meridian, because it is observed (Phenom. 2.) that when the beams of the *aurora* extend over a great part of the hemisphere, they are always bounded by an arch crossing the magnetic meridian at right angles.

SECTION

SECTION FOURTH.

Theory of the Aurora Borealis.

IN the preceding section we have deduced the nature of the *aurora*, merely by combining mathematical principles with the phenomena; the conclusions, therefore, are not drawn from *hypothesis*, but from *facts*, and must hold, as far as the facts are well ascertained, and the principles truly applied.——In this section we mean to propose something by way of hypothesis, to account for those phenomena.

The *light* of the *aurora* has been accounted for on three or more different suppositions: 1. It has been supposed to be a flame arising from a chymical effervescence of combustible exhalations from the earth. 2. It has been supposed to be inflammable air, fired by electricity. 3. It has been supposed electric light itself.

The first of these suppositions I pass by, as utterly inadequate to account for the phenomena. The second is pressed with a great difficulty how to account for the existence of *strata* of inflammable air in the atmosphere, since it appears that the different elastic fluids, intimately mix with each other; and even admitting the existence of these *strata*, it seems unnecessary to in-

A a 2   troduce

troduce them in the cafe, becaufe we know that difcharges of the electric fluid in the atmofphere do exhibit light, from the phenomenon of lightning.—From thefe, and other reafons, fome of which fhall be mentioned hereafter, I confider it almoft beyond doubt that the *light* of the *aurora borealis*, as well as that of *falling ftars* and the *larger meteors*, is electric light folely, and that there is nothing of combuftion in any of thefe phenomena.

Air, and all elaftic fluids, are reckoned amongft the non-conductors of electricity. There feems, however, a difference amongft them in this refpect; dry air is known to conduct worfe than moift air, or air faturated with vapour. Thunder ufually takes place in fummer, and at fuch times as the air is highly charged with vapour; when it happens in winter, the barometer is low, and confequently, according to our theory of the variation of the barometer, there is then much vapourized air: from all which it feems probable, that air highly vapourized becomes an imperfect conductor, and, of courfe, a difcharge made along à *ftratum* of it, will exhibit light, which I fuppofe to be the general cafe of thunder and lightning.

Now, from the conclufions in the preceding fections, we are under the neceffity of confidering the *beams* of the *aurora borealis* of a *ferruginous* nature,

nature, becaufe nothing elfe is known to be magnetic, and confequently, that there exifts in the higher regions of the atmofphere an elaftic fluid partaking of the properties of *iron*, or rather of *magnetic fteel*, and that this fluid, doubtlefs from its magnetic property, affumes the form of cylindric beams.——It fhould feem too, that the rainbow-like arches are a fort of *rings* of the fame fluid, which encompafs the earth's northern magnetic pole, like as the parallels of latitude do the other poles; and that the beams are arranged in equidiftant rows round the fame pole. At firft view, indeed, it feems incompatible with the known laws of magnetifm, that a quantity of magnetic matter fhould affume the form of fuch rings, by virtue of its magnetifm; but it may take place in one cafe at leaft, if we fuppofe the rings fituate in the middle; between two rows of beams, fo that the attraction on each fide may be equal. As for the beams, in their natural ftate, when not acted upon by caufes hereafter to be mentioned, they muft all be guided by the *earth's magnetifm* (I mean the caufe that guides the needle, whether it is in the earth or air I know not), and confequently all have their *north poles* downward, but whether any two neighbouring beams have the poles of the fame denomination, or of different denominations, acting upon each other, ftill the effect will be the fame, and their mutual action upon each other not difturb their parallelifm, nor the

position

position of the rings; because, whether the pole
mutually attract or repel each other, is of no
moment in this case, and the attraction of each
pole is alike upon the rings.

Things being thus stated, I moreover suppose
that this elastic fluid of magnetic matter is, like
vapourized air, an *imperfect conductor* of electri
city; and that when the equilibrium of electricity
in the higher regions of the atmosphere is dis
turbed, I conceive that it takes these beams and
rings, as conductors, and runs along from one
quarter of the heavens to another, exhibiting
all the phenomena of the *aurora borealis.*——The
reason why the diffuse flashes succeed the more
intense light of the beams is, I conceive, because
the electricity disperses the beams in some de
gree, which collect again after the electric cir
culation ceases.

Many of my readers, I make no doubt, will
be surprised to find, after having formed a con
ception that the relation betwixt the *aurora* and
magnetism was to be explained and demon
strated, chiefly if not solely, from the observa
tions on the disturbance of the needle during
the *aurora*, that no mention or use whatever is
made of those observations, in the preceding
sections. In fact, the relation above mentioned
is demonstrable without any reference to them;
notwithstanding which, they not only corrobo-

rate

rate the proof of it, but almoſt eſtabliſh the truth of the hypotheſis we are here advancing.

The variations of the needle during the *aurora*, as may be ſeen in the obſervations, are ſo exceedingly irregular, that after conſidering them a while, one would conclude this is the only fact aſcertained by theſe obſervations. However, I think we may deduce the following:

1. When the *aurora* appears to riſe only about 5, 10, or 15° above the horizon, the diſturbance of the needle is very little, and often inſenſible.

2. When it riſes up to the zenith, and paſſes it, there never fails to be a conſiderable diſturbance.

3. This diſturbance conſiſts in an irregular oſcillation of the horizontal needle, ſometimes to the eaſtward, and then to the weſtward of the mean daily poſition, in ſuch ſort that the greateſt excurſions on each ſide are nearly equal, and amount to about half a degree each, in this place.

4. When the *aurora* ceaſes, or ſoon after, the needle returns to its former ſtation.

Now, from theſe facts alone, independent of what is contained in the preceding ſections, I
think

think we cannot avoid inferring, that there is something magnetic *constantly* in the higher regions of the atmosphere, that has a share at least in guiding the needle; and that the fluctuations of the needle during the *aurora* are occasioned by some mutations that then take place in this magnetic matter in the incumbent atmosphere; for, it is certainly improbable, if not absurd, to suppose that the *aurora produces* this magnetic matter, at its commencement, and *destroys* it at its termination. Moreover, abstracting from a chymical solution of the metal, nothing is known to affect the magnetism of *steel*, but *heat* and *electricity*; heat weakens, or destroys it; electricity does more, it sometimes changes the pole of one denomination to that of another, or inverts the magnetism. Hence, we are obliged to have recourse to one of these two agents, in accounting for the mutations above mentioned. As for heat, we should find it difficult, I believe, to assign a reason for such sudden and irregular productions of it in the higher regions of the atmosphere, without introducing electricity as an agent in those productions; but rather than make such a supposition, it would be more philosophical to suppose electricity to produce the effect on the magnetic matter *immediately*. Hence then were we obliged to form an *hypothesis* of the *aurora borealis*, without any other facts relative to it than the *four* above mentioned, we ought to suppose it a phenomenon produced in

some

. In fine, the conclusions in the last section, and the hypothesis in this, afford a very plausible reason for the appearance of the *aurora* being so much more frequent now than formerly in these parts; if the earth's magnetic poles be like the centres of the *aurora*, as the phenomena indicate, it is plain the *aurora* must move along with them, and appear or disappear at places, according as the magnetic poles approach or recede from them; and hence it may be presumed that the earth's magnetic pole in the northern hemisphere is nearer the west of *Europe* in this century than it was in the last or preceding.—The observations upon the dip of the needle, however, if they have been accurately made, seem to indicate the approach of the magnetic pole to have been very little; the dip at *London*, according to Mr. *Cavallo*, was 71° $50'$ in 1576, and 72° $3'$ in 1775; but there is reason to suspect the accuracy of the instruments at so early a period as 1576; besides, we do not know in what proportion the dip of the needle keeps pace with the approach of the pole.

It may perhaps be necessary here, before the subject is dismissed, to caution my readers not to form an idea that the *elastic fluid of magnetic matter*, which I have all along conceived to exist in the higher regions of the atmosphere, is the same thing as the *magnetic fluid or effluvia* of most writers on the subject of magnetism.

netifm. This laft they confider as the efficient caufe of all the magnetic phenomena; but it is a mere hypothefis, and the exiftence of the *effluvia* has never been proved My *fluid of magnetic matter* is, like magnetic fteel, a fubftance poffeffed of the properties of magnetifm, or, if thefe writers pleafe, a fubftance capable of being acted upon by the magnetic *effluvia*, and not the magnetic *effluvia* themfelves.

Whether any of the various kinds of air, or elaftic vapour, we are acquainted with, is magnetic, I know not, but hope philofophers will avail themfelves of thefe hints to make a trial of them.

SECTION FIFTH.

An invefligation of the fuppofed effect of the Moon in producing the Aurora Borealis*.

SOME time after the author began his obfervations on the *aurora borealis*, it occurred to him that the phenomenon had more frequently happened about the change of the moon than at

Bb 2   any

* An effay on this fubject was firft publifhed by the author in the beginning of 1789, in Mr. *Davifon's Mathematical and Philofophical Repofitory.*

any other time; this produced the suspicion that the ærial tides occasioned by the moon might have some influence upon it. Granting this to be the case, it was obvious, the full moon must have an equal share with the new, though the phenomenon may often be then invisible, owing to the light of the moon.———Having now an enlarged list of observations, we shall resume the subject afresh, and examine what countenance the observations give to the supposition.

In the list of observations we have placed the moon's age, both with respect to change and full; collating, therefore, the whole number of observations to each particular number expressing the age, we shall have the following series:

Days past change and full.	0	1	2	3	4	5	6	7
No. of observations.	14	25	21	20	19	20	15	21

Days past change and full.	8	9	10	11	12	13	14.
No. of observations.	18	23	15	6	10	13	9.

<div align="right">(12)</div>

As the lunar revolution is completed in $29\frac{1}{2}$ days nearly, one half of a lunation is $14\frac{3}{4}$ days; hence the observations under 14 do not stand the same chance as the rest, there being only $\frac{3}{4}$ of the number of periods that have a day corresponding to this number: the number of observations under it ought therefore to be increased in the ratio

ratio of $\frac{3}{4}$ to 1, or be 12 inſtead of 9, in order
to make a fair diviſion of the terms of the ſeries.
Now the ſpring tides will fall almoſt wholly in
the firſt half of this period, and the neap tides
in the laſt; dividing the terms of the ſeries,
therefore, into two equal portions, taking half
of the odd intermediate one to each, the ſums
of the portions are as under.

	Spring tides.	*Neap tides.*
No. of *auroræ.*	144½.	107½.
Ratio	4 :	3, nearly, which

is favourable to the ſuppoſition.

It may be objected, that as the latter diviſion
contains the whole of the *ſecond* quarter of the
moon, when its light is ſtrong, and when it is
above the horizon all the time there is to obſerve
the *aurora,* the phenomenon is not noticed as
often as it takes place in that quarter.——This
may be right, but it ſhould be obſerved, that the
laſt quarter of the moon, which is wholly exempt
from this objection, falls in the ſame diviſion;
and both the firſt and third quarters, conſtituting
the other diviſion, are in part liable to the ſame
objection.

However, in order to determine whether this
objection is of ſuch import as to counterbalance
the apparent concluſion contained above, it may
be proper to find and compare the number of
obſervations

obfervations in the firft and laft quarters only.——
This being done, on the principle above ufed,
the numbers ftand,

First quarter, or fpring tides.   Laft quarter, or neap tides.

93½.   81.

From which it appears the phenomenon is ob-
ferved more frequently in the firft quarter of the
moon, though liable in part to the above ob-
jection, than in the laft quarter, which is wholly
free from it.

Prefuming then from what is done above, that
thofe periods of the lunar months, when the
higher tides are in the air, are moft fubject to
the phenomenon in queftion, it fhould be ex-
pected, that thofe times of the *day* when fuch
tides are in the atmofphere, fhould likewife be
more fubject to it than others.   Now the fpring
tides in the afternoon always happen in the in-
terval from 2 to 8 o'clock; confequently, the
opportunity of making obfervations upon the
phenomenon in this interval will *often* occur in
in winter, and *never* in fummer, owing to the
twilight.——It fhould feem then, that the winter
obfervations ought to favour the hypothefis more
than the fummer ones.——In fact, we find this the
cafe.   The obfervations in the months of No-
vember, December, and January, being arranged
and fummed up as above, give,

Spring

Spring.	*Neap.*
$40\frac{1}{2}$.	$24\frac{1}{2}$.

And thofe in the months of May, June, July, and Auguft, give,

Spring.	*Neap.*
$25\frac{1}{2}$.	$24\frac{1}{2}$.

As the tides are higher in fpring and autumn than in fummer and winter, the phenomenon ought, according to hypothefis, to occur more frequently in the two former feafons than in the two latter. The number of obfervations in the different months ftand thus:

Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
18	18	26	32	21	5	2	21	23	36	38	9.

The fmall number in June and July is undoubtedly owing in great part to the twilight; but the deficiency in December, January, and February, cannot be owing to the fame caufe.

Upon the whole, I think it is not improbable that the agitations caufed by the moon in the very high regions of the atmofphere, which we may fuppofe are not much agitated by the tempefts in the lower regions, may have fome effect upon the phenomenon in queftion; and the fuppofition is evidently countenanced by the feveral facts ftated above.

SECTION

SECTION SIXTH.

An investigation of the effect of the Aurora Borealis
on the Weather succeeding it.

VARIOUS have been the conjectures on this
subject offered to the consideration of the public :
some assert that the *aurora* has no sensible effect
upon the weather; others that it is very fre-
quently followed by rain soon after.

In the American Philosophical Transactions,
we find it observed that the barometer *falls* after
an *aurora.*

Having a large number of observations on the
aurora, together with those on the barometer
and rain, we are prepared to examine these opi-
nions, and we do it the rather because if any
thing can be ascertained on this head, it must be
regarded as a valuable discovery, considering the
present very imperfect state of meteorological
prognostication.

Since the spring of 1787 there have been 227
auroræ observed at *Kendal* and *Keswick ;* 88 of
the next succeeding days were *wet,* and 139 *fair,*
at *Kendal ;* now, in the account of rain, the
mean yearly number of wet days there is stated
at 217, and of course the fair days are 148 ;
hence the chances of any one day, taken at ran-
domₒ

dom, being wet or fair, are as thefe numbers.
But it appears the proportion of fair days to wet
ones fucceeding the *auroræ*, is much greater than
this general ratio of fair days to wet ones; the
inference therefore is, that the appearance of the
aurora borealis is a prognoftication of *fair weather.*

The only objection to this inference which oc-
curs to us as worth notice is, that the *aurora*
being from its nature only vifible in a clear at-
mofphere, this circumftance of itfelf is fufficient
to caft the fcale in favour of the fucceeding day
being fair, without confidering the *aurora* as
having any influence either directly or indirectly.
—This objection has undoubtedly fome weight;
but upon examinining the obfervations, it appears
that the *aurora* not only favours the next day,
but indicates that a feries of days to the number
of 10 or 12, are more likely to be all fair, than
they would be without this circumftance.

Of 227 obfervations, 139 were followed by 1
or more fair days, 100 by 2 or more &c. as under.

1	2	3	4	5	6	7	8	9	10	11	12
139	100	69	52	38	30	21	16	10	6	2	1.

According to the laws of chance, the proba-
bility of any number of fucceffive fair days is
found by raifing $\frac{148}{365}$ to the power, whofe index
is the propofed number of fair days; thefe pro-
babilities being multiplied by 227 will give what

the

the above feries ought to have been, if the *aurora* had no influence; it is as under.

1	2	3	4	5	6
92	38	15	6	2	1

From which it appears, there fhould not have been more than 1 *aurora* out of 247 followed by 6 fair days, and yet in fact there were 30; whence the inference above made is confirmed.

As for the different feafons of the year, I find the *aurora* is more frequently followed by fair weather in fummer than in winter; but the diftinction is not very confiderable.

It may be obferved that the largeft and moft fplendid appearances of the *aurora*, as they ufually happen in rainy and unfettled weather, they are frequently fucceeded by 1 or more wet days; but I do not find any of thofe very remarkable ones which happened on a fair day, was fucceeded by a wet one.

Upon examination of the effect of the *aurora* upon the barometer, I find, that fince the 19th of September, 1787, there have been 219 obfervations, and that in 120 of thefe inftances the barometer was rifen next morning, and fallen in 99.—This circumftance, therefore, corroborates the inference before made, that the *aurora* is a fign of fair weather.

General

General Rules and Observations for judging of the Weather.

NOTWITHSTANDING we have departed pretty much from our original design of expatiating on this subject, we think it may not be amiss to collect some of the facts and observations that are diffused through the work, which relate more immediately to the subject, and to add thereto a few more observations.

1. The barometer is highest of all during a long frost, and generally rises with a NE. wind; it is lowest of all during a thaw following a long frost, and is often brought down by a SW. wind. See page 112.

2. When the barometer is near the high extreme for the season of the year, there is very little probability of immediate rain. See page 151.

3. When the barometer is low for the season, there is seldom a great weight of rain, though a fair day in such a case is rare. See page 150. The general tenor of the weather at such times is, short, heavy, and sudden showers, with squalls of wind from the SW. W. or NW.

4. In summer, after a long continuance of fair weather, with the barometer high, it generally falls gradually, and for one, two, or more days, before there is much appearance of rain.—If the

fall

fall be sudden and great for the season, it will probably be followed by thunder.

5. When the appearances of the sky are very promising for fair, and the barometer at the same time low, it may be depended upon the appearances will not continue so long. The face of the sky changes very suddenly on such occasions.

6. Very dark and dense clouds pass over without rain when the barometer is high; whereas, when the barometer is low, it sometimes rains almost without any appearance of clouds.

7. All appearances being the same. the higher the barometer is, the greater the probability of fair weather.

8. Thunder is almost always preceded by hot weather, and followed by cold and showery weather.

9. A sudden and extreme change of temperature of the atmosphere, either from heat to cold or cold to heat, is generally followed by rain within 24 hours.

10. In winter, during a frost, if it begin to snow, the temperature of the air generally rises to 32°, and continues there whilst the snow falls; after which, if the weather clear up, expect severe cold.

11. The *aurora borealis* is a prognostic of fair weather. See Lilly 8, Sect. 6.

Appendix.

Appendix, containing additional Notes, &c. on different parts of the Work.

PAGE 8.

THE height of *Kendal* above the fea was fet down 25 yards, by eftimation only; I have fince found, by levelling with the barometer, that *Stramongate bridge*, at *Kendal*, is 46 yards above *Levens bridge*, to which the tide flows; though it feems the furvey for the intended canal makes the height lefs: I am not aware of any circumftance that could lead me into an error.

Mr. *Crofthwaite* has lately determined, by levelling with a very good theodolite, that *Baffen-thwaite-lake* is 70 yards above the level of the fea, and that *Derwent-lake*, which is 10 yards below his barometer, is 76 yards above the level of the fea; I make the laft mentioned lake 81 yards above the level of the fea, from barometrical obfervations; but if I have made an error by determining *Kendal* 5 yards too high, the refults of our obfervations will be reconciled *.

Page

* The height of the following places above the level of the fea have been determined as under; the obfervations with the barometer were made by myfelf, and thofe with the theodolite by Mr. *Crofthwaite*.

	From barom. obf.	From the theodolite.
Windermere lake - - - -	26 yards.	—
Dunmail-raife, barrow of ftones in the boundary of *Cumberland* and *Weftmorland*	245 —	275.
Leathes lake - - - - -	171 —	182.

My

manner by the united agency of magnetifm and electricity.

It appears then, that the difturbance of the needle during an *aurora* equally countenances the conclufions drawn in the laft fection, and the hypothefis adopted in this; and it may be accounted for on the hypothefis, as follows.

The beams of the *aurora*, being magnetic, will have their magnetifm weakened, deftroyed, or inverted, *pro tempore*, by the feveral electric fhocks they receive during an *aurora*; or perhaps the temporary difperfion and diffufion of the magnetic matter thereby, may confiderably alter its influence; when, therefore, the alterations on each fide of the magnetic meridian do not balance each other, the confequence will be a difturbance of the needle*.

B b   In

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* I conceive that a beam may have its magnetifm inverted, and exift fo for a time, becaufe the repulfion, acting longitudinally upon it, will only impel it in that direction, and not turn it round; juft as the north pole of a magnet may be applied to the north pole of a magnetic needle, without turning it round, by keeping the magnet exactly in the fame line with the needle, and thus making the needle act upon the centre. And I further conceive, that when the beam is reftored to its natural pofition of the north pole downward, it is effected, not by inverting the beam, wholly as a beam, (for this is never obferved in an *aurora*) but by inverting the conftituent particles, which may eafily be admitted of a fluid.

flaſhes, or *beams*, blended together, owing to the ſituation of the obſerver relative to them.

Theſe diſtinctions, and the terms appropriated for them, muſt be kept in view, in attending to the following phenomena.

PHENOMENON I.

The beams of the *aurora borealis* appear, at all places alike, to be arches of great circles of the ſphere, with the eye in the centre, and theſe arches if prolonged upwards would all meet in one point.

This is conformable to my own obſervations, and to all the accounts I have ſeen of the *aurora*.

PHENOMENON II.

The rainbow-like arches all croſs the magnetic meridian at right angles; when two or more appear at once, they are concentric, and tend to the magnetic eaſt and weſt; alſo, the broad arch of the *horizontal light* tends to the magnetic eaſt and weſt, and is biſected by the magnetic meridian; and when the *aurora* extends over any part of the hemiſphere, whether great or ſmall, the line ſeparating the illuminated part of the hemiſphere from the clear part, is half the circumference of a great circle, croſſing the magnetic meridian at right angles, and terminating

Z   in

Page 29.—The greateſt heat experienced for the laſt 5 years, at *Kendal*, was on the 1ſt of Auguſt 1792; but the heat of the preſent year, 1793, exceeded; the thermometer in the ſhade was 83° ½ on the 11th, and 84½ on the 15th of July.

Page 39.—There is a great diſcordance in the height of *Skiddaw*, as determined by the obſervations of different perſons, I have remarked that Mr *Croftwaite* made it 1050 yards above *Derwent lake*, I find ſince that Mr *Donald* made it 1090 yards above the ſea, and 958 above *Boſſenthwaite lake*. Mr. *Croſthwaite*, by a later admeaſurement, determines its height 1000 yards above *Derwent lake*.—On the 26th of Auguſt, 1793, I attempted its height by the barometer, for which purpoſe the following obſervations were made.

At 3h 30m P M the barometer upon the ſummit of *Skiddaw*, when the proper allowance for the riſe of the mercury in the reſervon was made, ſtood at - - - - - - - - - - 26.79 inches.
Mr. *Croſthwaite*'s barometer at *Keſwick*, allowing for the ſmall difference of the barometers when together, at the ſame time, ſtood at - - 29 715———
A detached thermometer above was, in the ſhade, - 46°.
A detached thermometer below was, in the ſhade, - 60°.
                                                        Now,

My obſervations were taken both in going to and returning from *Keſwick*, and compared with nearly cotemporary obſervations at *Kendal* and *Keſwick*; at the former time the air was dry, and at the latter moiſt: the elevations were found ſomething leſs by the later obſervations, but the difference was only 2 yards in *Leathes lake* and 9 in *Dunmail-raiſe*.

Now, by applying the theorem at page 81, we find the elevation of the upper barometer above the lower 945½ yards; whence, adding 10¾ yards, we get the height of *Skiddaw* above *Derwent lake* = 956¼ yards, and its height above the sea comes out 1037¼ yards.—It had been a good deal of rain on the morning of that day, and the clouds were just broken off at the time of the observations, the air remaining still very soft; from which circumstance I am inclined to think that the height above determined is rather too little; for I have found by repeated observations upon a hill 310 yards high, that the heights are found less by the theorem as the air is softer, *cæteris paribus*: I think therefore we may conclude *Skiddaw* to be nearly 1000 yards above *Derwent lake*, agreeable to Mr. *Crosthwaite*'s last measurment, till its height can be more exactly ascertained by a repetition of observations *.

AFTER

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* Mr. *Crosthwaite* makes the height of *Latrig*, another mountain in the neighbourhood of *Keswick*, to to be 319 yards above *Derwent lake*: by observations on the barometer the above mentioned day, I found its height 312 yards, which, for the reason assigned above, is probably too little.

Helvellyn is a mountain close by the road leading from *Kendal* to *Keswick*, about 8 miles from the latter place; it has always justly been considered higher than *Skiddaw*. On the 27th of August I made the following observations to determine its height.

At 1h 30m P. M. barometer at the summit, corrected as above,   26 69.
Barometer below, 10 yards above *Leathes lake*,   -   -   -   -   29.39.
A detached thermometer at the summit was   -   -   -   -   -   42° ½
A detached thermometer below was   -   -   -   -   -   -   -   54. .

From

AFTER I had observed the *aurora borealis* to to disturb the needle so greatly, as is related in the *addenda* to the observations on that head, I conjectured, *a priori,* that thunder-storms would do the same; accordingly, I watched the needle for a considerable time during the only thunder-storm we had at *Kendal* in the summer of 1793, namely, on the evening of the 3d of August; but, far from perceiving any unusual fluctuation, I could not discover the needle was perceptibly disturbed all the while, and it continued at the same station the next morning.

On the state of Vapour in the Atmosphere, &c.—
See page 134, and following.

AFTER making some experiments upon the effects of the condensation of atmospheric air, in a glass vessel, by means of a syringe, from which I find that repeated condensation produces a deposition of water upon the inside of the glass, and repeated rarefaction removes the same; also, having

From which the elevation of the upper barometer above the lower comes out 869½ yards; to which adding 171 and 10, we get the height of *Helvellyn* above the sea = 1050½ yards. But it should be observed the state of the air was still more moist than when I was upon *Skiddaw*, and the observation at top was taken during a shower; from which it is probable the height of *Helvellyn* above the sea is nearly 1100 yards. Mr *Donald* makes it 1108 above the sea.—About 200 yards below the summit there is a very fine spring, from which a large stream of water descends all the year round, with little variation in quantity at the different seasons, as my guide informed me; its temperature I found to be 38°.

having made fome experiments upon the effect
of heat on water thrown into the *vacuum* of a
common barometer, which tend to confirm thofe
the refult of which is given at page 134,—I am
confirmed in the opinion, that *the vapour of wa-
ter (and probably of moft other liquids*) exifts at
all times in the atmofphere, and is capable of bearing
any known degree of cold without a total condenfa-
tion, and that the vapour fo exifting is one and the
fame thing with* fteam, *or vapour of the temperature
of* 212° *or upwards.* The idea, therefore, that
vapour cannot exift in the open atmofphere
under the temperature of 212°, unlefs chymi-
cally combined therewith, I confider as errone-
ous, it has taken its rife from a fuppofition that
air prefling upon *vapour* condenfes the vapour
equally with *vapour* prefling upon *vapour*, a fup-
pofition we have no right to affume, and which
I apprehend will plainly appear to be contradic-
tory to reafon, and unwarranted by facts, for,
when a particle of vapour exifts between two
particles of air, let their equal and oppofite pref-
fures upon it be what they may, they cannot
bring it nearer to another particle of vapour,
without which no condenfation can take place,
all other circumftances being the fame; and it has
never been proved that the vapour in a receiver
from which the air has been exhaufted is pre-
cipitated upon the admiffion of perfectly dry air.
Hence, then, we ought to conclude, till the con-

D d   trary

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* Dr. *Prieftley* obferves in the fifth volume of his Experiments, page 225, that quickfilver evaporates not only *in vacuo* but when expofed to the atmofphere.

trary can be proved, that *the condenfation of va-pour expofed 10 the common air, does not in any manner depend upon the preffure of the air.*

All the facts, howevei, confpire to prove that the *temperature* of the an beais a ielation to the condenfation of vapour, thus, the utmoft force which vapoui of 212° can exert, is equivalent to the weight of 30 inches of mercury, and any greatei force than this, acting upon vapoui alone of that temperature, will condenfe the whole into water, and, if the temperatuie be lefs, then the utmoft force or fpiing of vapour is lefs, as is in-dicated by the table in page 134; and no doubt as the utmoft force decreales, the utmoft denfity will decreafe alfo, though probably not in the fame ratio. Hence, then, atmofpheric air, faturated with vapour, is fuch wherein the vapour, confi-dered abftractedly fiom the air in which it is diffufed, is at its utmoft denfity for the tempera-ture; in fuch cafe, if a quantity of atmofpheric air and vapour be taken, and mechanically con-denfed, a portion of the vapour will be condenfed into water, and give off heat; on the contrary, if it be expanded, or, which amounts to the fame thing, if a quantity be taken out of a re-ceiver, the iemainder will have its capacity for vapour increafed, as has been already obferved.

Though the preffure of the air does not pro-mote the condenfation of vapour, yet when the preffure is removed, evaporation is promoted; for under the receiver of an air-pump we find that

that the vapour from the wet leather rises as fast
as it can be pumped out, when the rarefaction
has proceeded to a certain degree.

In order the more to illustrate and confirm
the notion of vapour here laid down, we shall
now attempt to explain several facts, which have
been considered as involving difficulties, and we
believe some of them have never been accounted
for by others.

Dr. *Alexander*, in his *Experimental Essays*,
page 102, informs us, that from some experi-
ments he was induced to think, that blowing
upon the bulb of a thermometer with a pair of
hand-bellows would cool it, but upon trial found
it was always heated 1 or more degrees by the
operation.——Now, if a thermometer that has just
been dipped in water of the same temperature as
the air, be blown with a pair of hand-bellows as
above, it will be cooled several degrees. These
two facts I have proved frequently, from experi-
ment.——Again, Dr. *Darwin* (fee the note, page
136) found that air having been for some time
condensed, upon rushing out against the bulb of
a thermometer, cooled it several degrees, and a
dew was deposited upon the bulb.

The reason of these apparently difcordant facts
may be explained thus · the condensation of va-
pour in a pair of hand-bellows will precipitate a
portion of the infused vapour, which gives off its
heat to the air; and thus the temperature of the

air in the bellows being increafed, that of the thermometer, expofed to the current, will be increafed accordingly. In the fecond inftance, the water on the bulb of the thermometer being expofed to the current of air, quickly evapo-rates, and at the fame time abforbs the neceffary heat from the quickfilver. But in the third in-ftance the heat confequent to the condenfation was fuffered to efcape, whilft the condenfed va-pour or water remained in the air-gun; the air rufhing out was therefore of the fame tempera-ture as the furrounding air, and probably a great portion of the condenfed vapour remained me-chanically mixed therewith; a depofition of wa-ter upon the bulb of the thermometer was of courfe unavoidable, and this being refolved into vapour by its expofition, reduced the temperature of the thermometer.

In the Philofophical Tranfactions for 1777, there is a very interefting feries of experiments fhewing the effects of vapour in the receiver of an air-pump, when the air is exhaufted; the experiments were made by *Edward Nairne*, F. R. S. upon a pump on Mr. *Smeaton's* con-ftruction. He ufed two gages, one of which was the common barometer gage, which was of courfe an accurate méafure of the force or ela-fticity of the medium of air or vapour within the receiver; the other, called the *pear gage*, from its fhape, confifted of a glafs tube, capacious in the middle, and ending in a narrow neck, which
was

was clofe; the other, or open end, was, by a contrivance for the purpofe, let into a bafon of mercury before the air from without was fuffered to enter, and upon its admiffion the quickfilver was forced into the gage; the fpace occupied by the air being then compared with the whole capacity of the gage, gave the rarefaction of the permanent elaftic fluid or air.—The chief facts obferved were the following,

1. When the pump-plate leather was foaked in water, and the barrel of the pump well cleared of moifture, then, after working the pump for 10 minutes, the rarefaction indicated by the pear gage was very great, and exceeded what was obferved in any other circumftance, whilft that indicated by the barometer gage was often not $\frac{1}{500}$th part as great as the other; alfo, it was obferved that the rarefaction by the pear gage was *lefs* every time the experiment was repeated, but that of the barometer gage was always the *fame* at the fame time.

2. When the pump-plate leather was foaked in water mixed with fpirit of wine, the rarefaction by both gages was lefs than in the former cafe; but the refults in other refpects were fimilar.

3. The effects of different temperatures of the air upon the rarefaction were as follow:

Pump-plate leather being foaked in water.

Air in the room 46°—barometer gage 84—pear gage 20000.
———— 57 ————— 56 ———— 16000.

Pump-plate -

Pump-plate leather being soaked in water mixed with spirit of wine.

Air in the room 46°——barometer gage 76——pear gage 8000.
————————— 57 ——————— 49 ————— 1200.

4. When the leathers of the *piston* were soaked in water, the two gages nearly corresponded; but the utmost rarefaction in this circumstance was very small, being, for instance,

In one pump —— barometer gage 37——pear gage 38.
In another pump ——————— 34 ——————— 37.

5. When the pump, &c. were dry, the barometer gage was sometimes lower after working the pump 5 minutes, than after the operation was continued 5 minutes longer.

6. When the pump and plate were both dry, and the receiver cemented on to the pump-plate, the two gages nearly agreed, the rarefaction by both being about 600, in *damp* weather; but in *dry* weather, and in a still greater degree when a quantity of vitriolic acid was in the receiver, (which was always found to gain weight by such its exposure) the barometer gage indicated a greater rarefaction than the pear gage.

These facts, some of which the ingenious artist who made the experiments accounted for, seem most or all of them capable of a satisfactory explanation upon the theory of vapour we are here maintaining.——When the pump-plate leather is soaked in any liquid, and the pressure is so far diminished that the liquid boils, or turns into vapour, it is plain the pressure can be no further diminished;

diminifhed; and in fuch cafe, when the pump is wrought, it muft draw each time a portion of the remaining air along with the vapour, and thus the air in the receiver admits of a diminution almoft *ad infinitum*, and vapour generated inftantaneoufly fupplies the place of the air withdrawn; when air is let in, the vapour in the pear gage is condenfed, and there remains nothing but the fmall portion of air, with its faturating portion of vapour, at the top of the gage.——The reafon why the repetition of the experiment decreafed the rarefaction by the pear gage, was, that the frequent condenfations of air and vapour in the barrel of the pump muft have produced a depofition of water there, by which the effect was fooner at its *ne plus ultra;* for, when the vacuum of the barrel is not perfect, the quantity drawn from the receiver in a given time muft be lefs than otherwife. I have no doubt if the experiments had been repeated often enough, the leather of the pifton and the valves would have been in effect foaked with water, and the refult as ftated in the 4th fact: in this cafe, as foon as the fpring of the air in the receiver is weakened to a certain degree, working the pump does not avail, becaufe the vapour in the barrel, together with the refiftance of the valves, is juft fufficient to counteract the fpring of the air within; hence the rarefaction by the pear gage is then fcarcely greater than by the barometer gage.

Experience proves that fpirit of wine rifes fooner into vapour than water; confequently the
<div align="right">rarefaction</div>

rarefaction by the pear gage, when the pump is wrought a given time, must be less than when water is used. Also, it follows *a priori*, that the cooler the circumambient air, other circumstances being the same, the greater must the rarefaction be by both gages.

When by long pumping a quantity of vapour is collected in the barrel of the pump, I conceive a portion of it may, during the operation, escape again into the receiver, this will account for the 5th fact.

I do not see how the 6th fact can be explained without supposing that the elasticity of dry air, when greatly expanded, decreases in a greater proportion than its density; it is true that the increase of cold in the receiver, and the less vapour there is in the air at first, the more will the rarefaction indicated by the barometer gage exceed that of the pear gage; for, it cannot be reasonably supposed that when the rarefaction is at its utmost degree, the proportion of vapour to air in the receiver is no greater than at first; I conceive, therefore, that the air condensed in the pear gage is always saturated with vapour, unless perhaps when the vitriolic acid is in the receiver, and of course its bulk, *cæteris paribus*, greater than before: but this alone is not sufficient to account for the observed differences of the gages.

THE END.